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NOTICE.

Beginning with Vol. XVI., each article will have a paging of its own, and the position of an article in a volume will be indicated by the number placed at its head.

It is hoped that this arrangement, which enables us to print papers independently of one another, will ensure a more rapid publication of the material than has been possible heretofore.

All communications relating to this Journal should be addressed to the Director of the College of Science.

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JOURNAL OF THE COLLEGE OF SCIENCE, IMPERIAL UNIVERSITY,
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VOL. XVI, ARTICLE 1.

Notes on the Raised Coral Reefs in the Islands of the Riukiu Curve.

By

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With 2 Plates.

In the southern seas of Japan we meet with the reef corals of both recent and more remote ages. They are not only found in Formosa, our new territory, but also in the islands of the so-called Riukiu Curve.* The following notes which treat of these coral reefs are based upon observations made on my geological trip to those islands during the nine months from July 1899 to March 1900.

I. DISTRIBUTION OF RAISED CORAL REEFS IN EACH ISLAND GROUP.

The Riukiu Curve consists of many scattered groups of islands, arranged in a curve extending over hundreds of miles between Formosa and Kyūshū. The southernmost is called the Saki-shima

* The name was first proposed by Prof. B. Kotô, *Journ. Geol. Soc. Tōkyō, Vol. V. No. 49 (1897)*. The word Riukiu is transliterated "Loochoo" on foreign maps.

group† (See Pl. II), on the north-east of which lies the Okinawa group. Immediately on the north of the Okinawa group there is the so-called Ōshima group, which, in fact, is merely its northern continuation. A row of very small islands lying to the north-west of the Ōshima group is called the Tokara group. Between these island groups and Kyūshū, there is the Ōsumi group consisting of a few scattered islands, the largest of which are Yaku-shima and Tanega-shima.

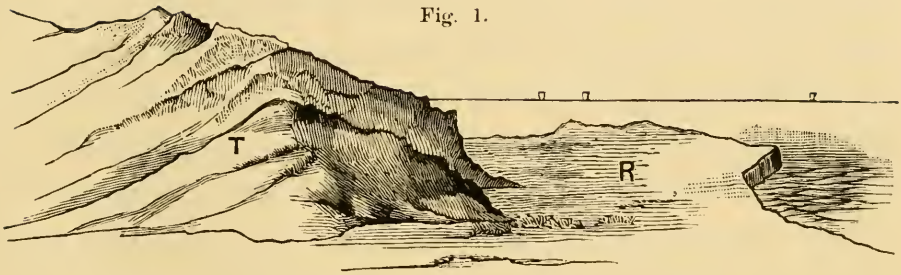
The Saki-shima Group.

The Saki-shima group is divisible into two subgroups, the Yaeyama and the Miyako. The former has, besides the two large islands of Iriomote and Ishigaki, ten smaller ones, called respectively Yonaguni-jima, Hatoma-jima, Kuro-shima, Aragusuku-jima, Nakano-gan-jima, Hateruma-jima, Taketomi-jima, Kobama-jima, and Kayama-jima.

Yonaguni-jima is situated in the westernmost part and prior to our acquisition of Formosa was known as the western limit of Japan. This island is divisible into eastern and western sections by two hill ranges called Urabu and Kobura, having a vast plateau between them. Raised reefs were observed over the whole area of this plateau and along the outer margin of the hill ranges. They are also widely distributed in the western and northern parts of the island, while in the other parts they are now found only in detached areas on the table-land of Tertiary sandstone. Although the culminating point of the hill ranges attains an elevation of 700 ft. and although the foundation covered by reefs is composed of the sediments of the Miocene epoch with a dip generally to the east and the strike running either

† *Shima* (pronounced *Jima* in combination) means island or islands.

Fig. 1.



T Tertiary sandstone. R Raised coral reefs.

from NNE to SSW or from N to S, yet the raised reefs are entirely composed of horizontal beds and form an extensive table-land less than 100 ft. in height (Fig 1). From the facts above stated it is to be inferred that the present island was formerly separated into two by a channel of shallow water, in which the coral polyps built their thick reefs, and that by a subsequent upheaval the two islands were united into a single one. The reefs are at present in two or more terraces near the shore, and their entire thickness is about 30 ft., while the elevation to which they have been upraised attains a height of several hundred feet above the level of the sea. The recent sand on the sea coast of the northern part of the island is nothing but a heap of the shells of the Foramimfera, *Calcarina spengleri* Linné.

Iriomote-jima is composed almost entirely of Tertiary sandstone, the layers of which are more or less regularly inclined, just as in Yonaguni-jima. The highest peak has an elevation of about 1,500 ft., but the raised reefs, only 30 or 40 ft. in thickness and quite horizontally bedded, are met with only here and there within a very limited area. In the south-eastern corner called the Haemi region, however, the reefs 20 or 30 ft. in thickness are seen in a continuous sheet on a table-land more than a hundred feet high : this is the case also in Yonaguni-jima.

Two small islands, Kayama-jima and Kobama-jima, have only a

few remains of ancient fringing reefs built upon the Palæozoic sediments. The northern half of Taketomi-jima is composed of Palæozoic rocks, chiefly of compact quartzite ; but the southern half is covered entirely with a flat layer of raised reefs about 30 ft. in thickness. The raised reefs of Hatoma-jima, also about 30 ft. thick, completely surround a small Tertiary hill called Nakamori, which is situated in the center of the island and has an elevation of 117 ft. Kuro-shima, Aragusuku-jima and Hateruma-jima are all entirely made up of the raised reefs, the highest point of the last named island being 220 ft. The others attain an elevation of only 30 to 40 ft.

Ishigaki-jima, at the time of the formation of the raised reefs probably consisted of four small islands (Pl. II A. B. C. D), near which the fringing reefs were built. The fundament of these reefs evidently consisted of Palæozoic rocks, Tertiary limestone and sandstone, and the andesites, as they are now seen directly underlying the reefs which show no sign of disturbance since their formation. The distribution of the reefs is in three great groups. The first group is in the southern part of the island. It is widest in area occupying the coast region for about ten miles with a breadth of about two miles. The reefs form three successive terraces, the uppermost of which attains an elevation of about 100 ft. above the sea-level. This terrace extends from the northern part of Shiraho-mura to the neighbourhood of Moriyama-mura. The second terrace, 20 or 30 ft. lower than the first, extends from the vicinity of Miyara-mura to the southern foot of Bannā hill. The third or lowest terrace is found along the shore near Shika-mura and other villages. The second group was developed along the shores of the two supposed islands (C and D) which are situated to the north-east of the others (A and B). At the present time we see the table-land of Palæozoic rocks covered with coral reefs 20 to 30 ft. thick along the eastern and western coast of Ishigaki-jima,

while on its eastern coast the reefs have been almost entirely washed away and remain only in detached areas of small extent. The third group was found in a flat piece of land between the largest (A) of the four islands and the one (B) to the west of it; it also extended to the northern coast of the former. The remaining portions of the coast of Ishigaki-jima are at present covered with a few remnants of ancient low coral reefs. Generally speaking, the reefs of this island are not thicker than 30 or 40 ft. having been built on a wide plateau now raised in some places to an elevation of several hundred feet above the sea.

The Miyako subgroup consists of the islands of Miyako, Shimoji, Irabu, Kurima, Ikema, Ōgami, Tarama and Minna. A very noticeable fact is that all these islands, except one, are built entirely of the raised coral reefs. The island of Miyako, which gives the name to the subgroup, is the largest. It is wholly destitute of mountains. The surface is therefore quite flat, with a coast line of about 40 miles. The highest point has an elevation of 378 ft. and is called Nobaragoe, being situated near Nobara-mura. In the south-eastern part of the island the reefs are thicker than elsewhere and present a perpendicular cliff along the shore, while towards the west they slope down gradually until they pass into the Alluvial plain of the south-western corner of the island. As in other islands terraces are also observable in the reefs of the southern coast westward from Tomori-mura.

Irabu-jima attains an elevation of 300 ft. in its eastern part, whence it gradually slopes down towards the south-west. Ikema-jima, Tarama-jima, and Minna-jima have elevations of about 100 ft., 105 ft., and 15 ft. respectively. In Ōgami-jima the reefs are found only on the outer margin of the island. It should here be added that the above mentioned reefs are all horizontal, except in a very limited area in the southern part of Tarama-jima, where they incline towards the south at an angle of 30.°

The Okinawa Group.

This group is composed of the main island, Okinawa, (together with more than 17 dependent islands), and of the two subgroups of Iheya (with 5 islands) and Kerama (with more than 12 islands), and also four other islands named Kume, Tonaki, Aguni, and Tori.

Okinawa-jima has a coast line of about 200 miles, and is divided administratively into three districts or *gun*, called Kunchan, Nakagami and Shimajiri. In geological time, the Palæozoic mountain-range of which the first two districts are mainly composed, formed a long island, while the district of Shimajiri was entirely under water. During that time the reefs were built chiefly along the southern part, covering an extensive area of Tertiary rocks which now form the whole surface of Shimajiri, and also a part of the surface of the Palæozoic formation. The thickness of the reefs in Okinawa is small in comparison with their great extent, being considerably smaller than in the other islands, for instance, in the Miyako subgroup. The following table shows the elevations of raised coral reefs above the sea-level :

Ōmine-san (in Shimajiri)	121 ft.
Sunaga-jima (in Shimajiri)	142 ft.
Sōjun-yama (near Tomori in Shimajiri)	151 ft.
Shuri	496 ft.
Yoza-jima (in Nakagami)	557 ft.
Benga-dake (near Naha)	598 ft.

That the reefs do not attain a great thickness is shown by the fact, that when a boring is made from the surface, the underlying Tertiary (Pliocene) rocks are met with at the depth of about 30 ft. In a geological age not far removed from the recent epoch the district of Shimajiri was in all probability entirely covered with the coral reefs, and the scattered patches now seen here and there are to be looked

upon as mere relics of the once continuous rocks, slowly worn away by denudation (Pl II). The eastern half of the district forms a plateau several hundred feet in height. Towards the east it shows a steep escarpment generally with a belt of flat Alluvial plain lying at its base, while towards the west it slopes gently, often exhibiting terraces and ending at the shore in cliffs only a few yards in height. The raised reefs are found not only in Shimajiri, but also in the district of Kunchan, on the east coast near Kin and in the northern part of the tongue-shaped peninsula of Motobu on the west coast, forming in both places a plateau.

Running parallel to the longitudinal axis of Okinawa-jima and near its eastern coast, are six small islands. The base of these islands, except Ike-jima and Kudaka-jima, which are built up entirely of coral reefs and have an elevation of 30 to 40 ft., is also composed of Tertiary rocks, upon which the raised reefs are placed horizontally just as in Shimajiri. In Hianja-jima the eastern part is the most elevated, and the reefs are here developed to the greatest thickness.

In Sesoko-jima and Kouri-jima, the center of the island is composed of a Palæozoic limestone. This limestone is surrounded by a belt of reefs about 100 ft. in thickness, which in Sesoko present two or three terraces. Ie-jima, which is remarkable for having a huge pointed rock rising out of the surrounding hills in the central part of the island, has, for its fundament, Palæozoic rocks which are however for the most part covered with the coral reefs. The reefs form here as elsewhere an extensive plateau and have a thickness of perhaps 100 ft. or more. The above mentioned pointed rock is a compact Palæozoic quartzite. Minna-jima is a coral island only a few yards high, while Yagaji-jima has the reefs over only a very small area. The Kerama islands are, so far as I know, entirely destitute of raised reefs. According to Mr. T. Kuroiwa, the old coral reefs in Kume-jima and Aguni-

jima and in the Iheya subgroup and Kei islands are very limited in extent. In Kei-jima, the old reefs are found in small detached areas only in its western part, the rest of the island being composed of heaps of coral fragments of a very recent origin.

Far to the east of Okinawa-jima there are three isolated islands, known as South Borodino (Minami-ōagari), North Borodino (Kita-ōagari) and Rasa. The coral reefs seem to cap these islands and attain in the first a height of 250 ft. above the sea, while in the second and third the highest points are not over 150 ft. The reefs of South Borodino are said to form terraces. Another isolated group of small islands, called the Pinnacles, lies far to the north-east of the Yaeyama subgroup. In one of them called Hoa-pin-su (Waheizan) Mr. T. Kuroiwa saw the traces of old reefs on the southern, western and eastern sides.

The Ōshima Group.

Ōshima, with the four large dependent islands, Kikaiga-shima, Tokuno-shima, Okinoerabu-jima, and Yoron-jima, constitutes the Ōshima group, and lies immediately to the north of the Okinawa group.

In Okinoerabu-jima, the Palæozoic hills of small extent running from north-east to south-west, are found encircled by the raised reefs forming a large plateau, which attains an elevation of about 200 ft. above the sea, while the older rocks have, at a place called Ōyama, an elevation of 687 ft. In the reefs a few terraces are observable near the coast, where they show cliffs 20 to 30 ft. in height. Yoron-jima, which I was unable to visit, probably show a distribution of the reefs similar to that in Okinoerabu.

The foundation of Tokuno-shima is made up of Palæozoic and plutonic rocks, which rise to the height of 2,207ft. above the sea. The

reefs which are found upon this foundation form an extensive table-land in the southern, western and south-eastern parts of the island. Near Ketoku-mura in the north-eastern part of the island, the reefs are scattered in small areas and have a height of only about 50 ft., with a slight inclination towards the coast. They appear to have been originally built in the valleys of the Palæozoic mountains.

Kikai-ga-shima, with a coast line about 20 miles in length, consists of a Tertiary sandy shale, entirely covered with raised coral reefs, which in some places give rise to successive terraces. The shale is exposed only in the western and eastern parts, as at the steep cliff on the south of Sōmachi. Here it is covered with a reef from 30 to 40 ft. in thickness. The highest part of the cliff lies at Mābi, and is about 684 ft. above the sea-level.

Ōshima is a large island composed of Palæozoic rocks. The greatest elevation is found on a peak 2,300 ft. in height. The reefs are formed only upon the small tongue-shaped plateau on the north. On its eastern coast the reefs are elevated about 20 or 30 ft., while on the west they have been almost entirely eroded, leaving only on the north-western corner, some relics which are a few feet in thickness.

II. GENERAL CONSIDERATION.

The coral formation of more remote age, which always stands upon the eroded strata, forms fringing reefs on the islands composed of older rocks, or somtimes separate islands with entirely covered foundations. The latter type is observed at Hateruma-jima, Aragusuku-jima, Kuro-shima, Miyako-jima, Irabu-jima, Ikema-jima, Shimoji-jima, Kurima-jima, Minna-jima, Tarama-jima, Ike-jima and Kudaka-jima. Kikai-ga-shima, Hianja-jima and Miyagusuku-jima are a modification of this type and are reefs with their foundations exposed at the cliffs above the sea-level.

The recent coral reefs of southern Japan, scarcely exposed above the sea-water, are all fringing reefs; there being found neither atolls nor barrier reefs among them. The coral shows luxuriant growth along a line running parallel to the sea coast and at a few hundred feet from it. Between the fringing reefs and the sea-beach, there is, sometimes, a flat sandy bottom with a few groups of living corals. It is frequently so shallow, that we can wade across it at low tide. On the north-east of Miyako-jima, are the vast and dangerous rocks of Yaebise, consisting entirely of recent reefs, which are scarcely above the level of the sea at low tide. The islands known as Kikai-ga-shima, Miyako-jima and others must have been of this type in past time. The coral islands of recent formation are nothing but heaps of coral fragments; as Yuni lying between Hatoma-jima and Iriomote-jima, and the Kei islands on the west of Naha.

Although the strata of older sediments in the Riukiu Curve are all inclined, which is a result of the upheaval of the islands above the sea, the reefs lying upon them have as a rule remained horizontal, the exceptions being the locally disturbed ones found at Tarama-jima, Tokuno-shima, and other places. This shows that a gradual depression and elevation took place after the formation of the Riukiu Curve.

The raised reefs are mostly a true coral formation and homogeneous in structure. But in some places as at Tarama-jima there is, besides, a thick Foraminiferal deposit which attains a thickness of 10 ft. and is interbedded between two successive coral reefs. The species found in such a zone at Kamezu (in Tokuno-shima), Unten (in Okinawa-jima) and Yoda (in Okinoerabu-jima) is gigantic *Operculina* (Pl. I). In the south of Okinoerabu-jima the raised reefs consist essentially of corals, there being no layer of sand. Towards the north the coral layers are found interstratified with sand layers. At Kametoku in Tokuno-shima there are found thick beds of loose sand

and conglomerate in the reef coral. At Ōshima, we already find the greater part of the raised reef consisting of coral fragments, as well as of a brownish sand like some Diluvial deposits common in Japan. The fact seems to indicate an incomplete development of the coral formation on these islands and we may fix the limit of the coral reefs of the western Pacific at about 29° N.L.

When the recent corals are found close to an older reef, their boundary is not sharply defined; however they may be distinguished from each other by position, structure and colour. The older reefs are generally highly elevated while the recent ones are exposed only at low tide. The corals in the raised reefs have mostly lost their structure through the dissolving action of the water. I could only recognize among them the three species of *Favia*, *Porites* and *Fungia* (?). The older corals are also weathered and show a yellowish brown colour, and have sand-grains filling up the interstices of the skeleton. Finally the older reefs, on the exposed surface, are altered to a mass resembling *terra rosa*, frequently with a thickness of several feet. The recent corals show a well-preserved structure, and generally appear whitish in colour, only those on the surface being grayish.

All the raised coral reefs are homogenous in appearance throughout their whole thickness, there being apparently no mark of varying age in their different parts. The terraces in those reefs, as observed at Yonaguni, Ishigaki, Miyako, Irabu, Okinawa, Sesoko, Ie, Miyagusuku, Okinoerabu, Kikai, and other islands, may have been formed in the intervals between successive changes of sea-level, or the development of the coral formation from its beginning to its end may have been not equally extensive.

The elevations of the principal raised reefs are as follows:

Minna-jima	10—20 ft.

Kuro-shima		20—30 ft.
Ike-jima	about	100 ft.
Tarama-jima		105 ft.
Kita-ōagari-jima		150 ft.
Rasa-jima		150 ft.
Hateruma-jima		220 ft.
Minami-ōagari-jima		250 ft.
Irabu-jima	less than	300 ft.
Miyako-jima		378 ft.
Shimajiri (in Okinawa-jima)		600 ft.
Kikai-ga-shima		684 ft.

The two islands between 600 and 700 ft. in height, namely Kikai-ga-shima and Okinawa-jima, are composed of foundation rocks capped with thin reefs. All the other islands are of coral formation, with other rocks hidden under the sea. Their heights are however too great to admit of an explanation of the origin by the Elevation Theory. But according to F. Dahl who maintains the Depression Theory, the reefs of the Bismarck Archipelago show the very great height of 300 metres, just as in the case of Miyako-jima and others. According to E.C. Andrews, most of the raised reefs of the Fiji islands have been elevated from 800 ft. to 1050 ft. above the sea. The reefs in Timor which are considered by K. Martin as belonging to the Diluvial epoch, attain the height of about 600 metres. Those in north Luzon which belong to Pliocene were upheaved even to the height of 1400 metres.

The foundation of the raised reefs consists of Tertiary and Palæozoic sediments as well as igneous rocks. In the Saki-shima group, the reefs lie upon inclined Miocene rocks: in the Okinawa group upon still more recent Tertiaries. In the Riukiu Curve, the raised reefs are covered only by the weathering product of the reef, and by no younger deposit. The loose sand resembling a Diluvial deposit is mostly found

interstratifying coral layers in the northern part of the Curve.

Fossils of Mollusca and Brachiopoda found in the raised reefs are mostly casts. Those from the vicinity of Naha and Shuri in Okinawa-jima belong to the genera *Fusus*, *Conus*, *Cardium*, *Mactra*, *Tellina*, *Tapes*, *Chione*, *Limopsis*, *Arca*, *Pectunculus*, *Pecten*, *Waldheimia* and *Terebratula*. *Waldheimia picta* Chemn., *Terebratula japonica* Sow. (young ?), and *Terabratula caput-serpensis* Linn., are well preserved. The most conspicuous fossil found in most of the reef is *Lithothamniscum nahaense* Heydrich which is a species founded by F. Heydrich after studying the specimens from Naha. His description is as follows (*Journ. Geol. Soc. Tōkyō., Vol. VII, No. 80, 1900*) :—

> Der Thallus bildet flache 0.3—0.5 mm. dünne über wilde fossile Korallen ausgebreitete Krusten. Die Ausdehnung der Krusten mag etwa 3—5 cm. betragen haben; ob dieselben grösser gewesen sind, lässt sich nicht mit Bestimmtheit angeben, da das Substrat häufig zerbrochen und durch Druck wieder fest zusammengefügt wurde. Das Dickenwachsthum ist in Folge dessen nicht sicher nachzuweisen ; doch so viel steht fest, dass recht oft eine Schicht über die andere gewachsen ist, sodass 2-3 Thallusplättchen übereinander gelagert erscheinen. Eine ausgeprägte Basalschicht, wie sie bei ähnlichen recenten Formen sich vorfindet, ist nicht nachweisbar, sodass die Zellen fast überall regelmässig quadratisch mit etwa 12 μ. Seitenlänge erscheinen. Ob die im Querschliff gezeichneten zwei kleinen Bögen Conceptakel enthalten, konnte nicht festgestellt werden, wohl aber was durch Zufall ein kleines Stück Thallusoberfläche auf einen abgeschlagenen Stück Substrat freigelegt, welches Conceptakel enthielt. Dieselben sind etwa 200 μ. in Durchmesser und 60 μ. hoch mit scharf markiertem centralen Porus. Sie sind von flachgewölbter Form und liegen allem Anschein nach sehr flach, würden also bei zunehmendem Dickenwachsthum nicht in den Thallus versenkt werden.

Bryozoa are not rare in the raised reefs of Naha. The Echinoid, *Echinanthus testitudinarius* Gray, are found in Moriyama (in Ishigaki-jima), Unten (in Okinawa-jima) and Kametoku (in Tokuno-shima).

There are many species of Foraminifera and Radiolaria. *Textularia*, *Amphistegina*, *Triloculina*, *Planòrbulina*, *Rotalia* and *Globigerina* have been collected from Shuri ; *Rotalia* and *Amphistegina* from the Foraminiferal sand of Yōmura in Ōshima. A gigantic *Operculina* (Pl. I) is found numerously in the reefs of Okinawa-jima, Tokunoshima and Okinoerabu-jima, and is always well preserved.

From the above description we may draw the following conclusions :—

1. The raised reefs in the Riukiu Curve are mostly later than the Tertiary, and are overlaid by recent rocks.

2. These reefs are horizontal, in contrast to the inclined beds of the substratum.

3. In the ancient time they either covered the rocky sea-bottom, or fringed the margins of islands.

4. The northern limit of the ancient reefs in the western Pacific is 29° N.L.

5. The maximum elevation of the raised reefs in the Riukiu Curve is 684 ft.

6. They are distinguished from the recent reefs by their position, structure and colour.

7. The raised reefs are often found in the shape of terraces.

8. The reefs exhibit a character like those now growing under the sea water of the same region, and have been upheaved after a gradual depression.

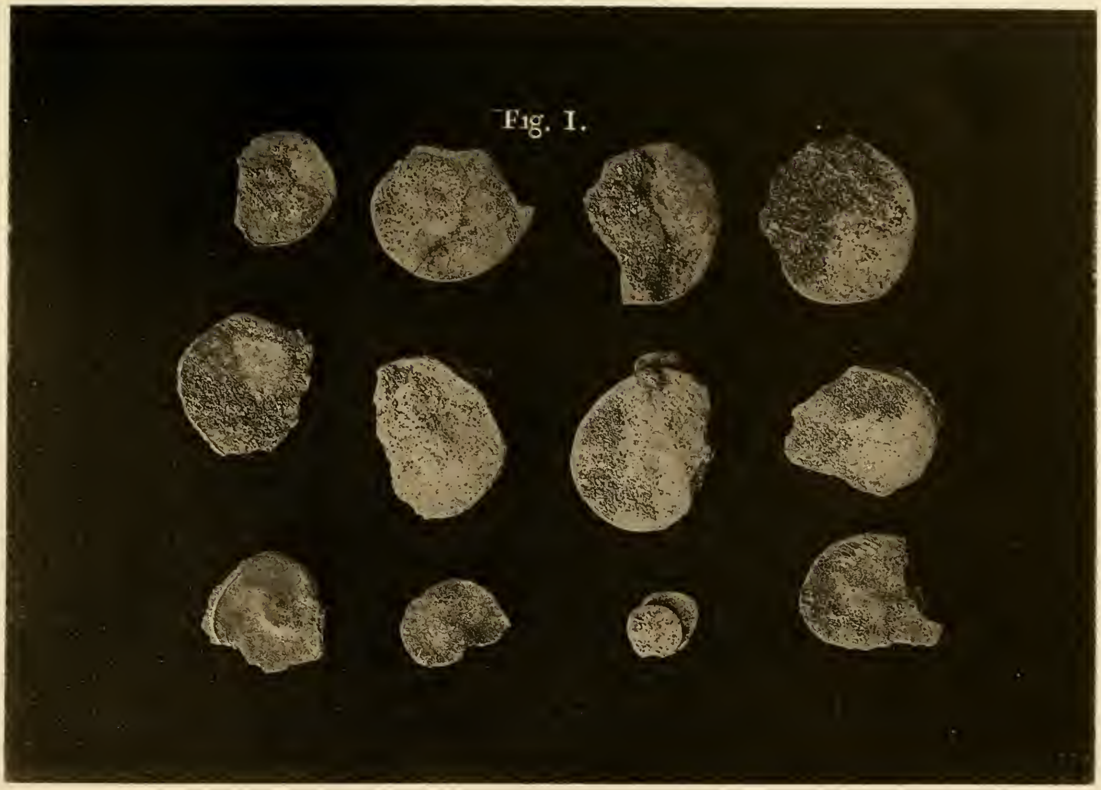
October 1900.

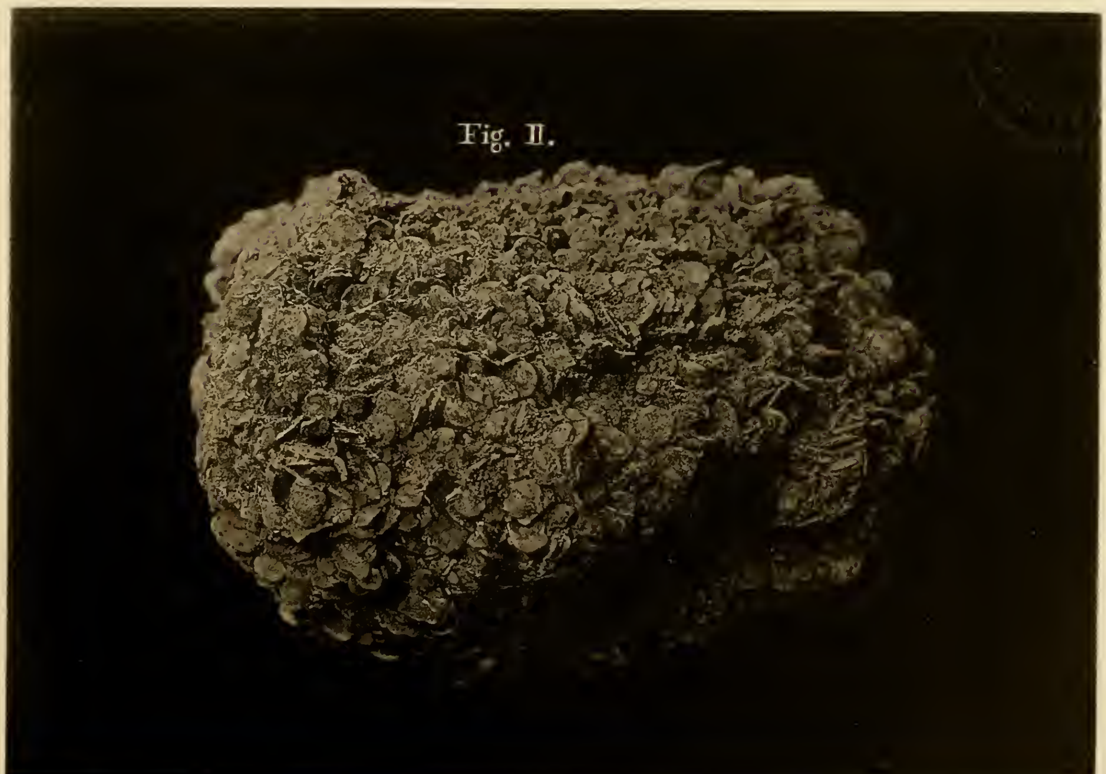
PLATE I.

Plate I.

Fig. I.—Gigantic specimens of *Operculina sp.* (natural size); from Kamezu in Tokuno-shima.

Fig. II.—Foraminiferal rock consisting wholly of the shells of *Operculina* (not reduced in size); from Yoda in Okinoerabu-jima.





Yoshiwara, On Raised Coral Reefs of the Riukiu Curve.

PLATE II.

Plate II.

The plate II shows the geographical distribution of the raised coral reefs in the Riukiu Curve.

Yoshiwara, On Raised Coral Reefs of the Riukiu Curve.

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Geologic Structure of the Riukiu (Loochoo) Curve, and its Relation to the Northern Part of Formosa.

By

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With 5 Plates.

CONTENTS.

PART I.—Introduction.

The Riukiu Curve,† consisting of all the islands lying between Kyūshū and Formosa, belongs partly to the Riukiu Islands and partly to the Province of Ōsumi; and is in all respects very little known. As for the geology of these islands, no reconnaissance survey of them had been made prior to the trip, the results of which this paper embodies. On the other hand, Formosa, our new territory, has been studied by many geologists, and the results of their studies have been partly published. Our Imperial University has sent in the last five years several naturalists to Formosa. Among them were Profs. B. Kotô and M. Yokoyama, who made geological observation, the former in 1897 and the latter in 1898. I was sent to visit Riukiu and Formosa, for the purpose of ascertaining their geological connection. After a trip of about one month in the northern part of Formosa, I spent nearly half a year (from July to December 1899) in travelling through the Riukiu Islands. With the kind assistance of the officers of the Okinawa Prefecture (the local government of Riukiu), I was able to visit nearly all the islands, which are about 65 in number. Only Kume-jima, Aguni-jimá, Tonaki-jima, Tori-shima, the Iheya subgroup, the very small uninhabited islands, and some islands in the Kerama subgroup have not been studied. All of these, however, have been visited by others, who have furnished me

† This name has been proposed by Prof. B. Kotô. (*The Journal of the Geol. Society of Tōkyō* Vol. V, No. 49, 1897.)

with geological specimens and information, either published or in manuscript. Mr. T. Kuroiwa visited the islands of Kume, Aguni, Tonaki, and the Iheya subgroup, and his notes in part appear in "*The Journal of the Geological Society of Tōkyō.*" The uninhabited islands lying at a distance from other islands of the Riukiu Curve have been examined, formerly by the Prefectural officers, and also by Japanese and foreign naval officers, and recently by Messrs. M. Miyajima and Kuroiwa. In travelling through Okinawa-jima, I was with Prof. Yokoyama, who gave me many kind suggestions respecting my investigations. After having furnished my observations in the Riukiu Islands, I spent about three months in crossing through the Ōshima group, visiting all members of the group except a few islets. The geology of the islands lying between the Ōshima group and Kyūshū has been treated in Mr. K. Nishiwada's work on Yaku-shima and Tanega-shima, which was published in "*The Journal of Geography, Tōkyō*" (1895). The Tokara group has been visited by Mr. M. Yamagami; while the structure of a few remaining islands can be seen in the General Geological Map of Japan (1:1.000.000) published in 1900 by the Imperial Geological Survey.

As to the northern part of Formosa, Gordon, Jones, Richthofen, Swinhoe and Tyzack have written geological notes. Messrs. Y. Ishii, K. Inoue and Y. Saitō have successively worked as chief geologists to the local government of Formosa. The valuable reports of these three observers have been published in Japanese.

The present paper will treat of the geology of the northern part of Formosa and of the islands lying between Formosa and Kyūshū. The results of my study of the raised coral reefs in Riukiu and Ōsumi is embodied in another note.

My sincere thanks are due to Prof. Jimbō who has with great kindness given me his help in the revision of this paper.

PART II.—Literature.

Our first knowledge of the natural history of the Riukiu Curve is due to the expedition of an American squadron in the years 1852, 1853 and 1854, under the command of Commodore M. C. Perry. The topographical survey was limited to Okinawa-jima, and the geological descriptions were made chiefly by R. G. Jones (Report made to Commodore Perry of a Geological Exploration &c. of the Island of Great Lewchew.——*Narrative of the Exp. of an Am. Squadron to the China Seas and Japan &c.* Vol. I p. 184 & Vol. II p. 53). He states: "Commencing at the southern end, we have uniformly an aluminous rock, sometimes pretty compact, and sometimes running into shale; from it comes all the clay or common soil of this part of Lew Chew. This rock or clay is pierced and overlaid by limestone running N about 60°E, and rising to pinnacled ridges, so as to deceive the eye at the distance of only a few hundred feet. About 17 miles north of Napha, a very coarse gneiss begins to make its appearance, and soon becomes the prevalent rock, overhanging the sea-shore in bluffs of most contorted stratification, or running out in great ledges of jagged forms. The limestone is, however, seen yet occasionally, running slantingly across the island, in broken ridges, as before. At the village of Nacumma, on the west side of the island, say 42 miles north of Napha, we come to a small extent of granite hills, piercing through the gneiss. It is the only granite that I have seen on the island.................... Beyond this, the gneiss begins to be mixed up with strata of clay-slate, to which it at length entirely gives place; and at Farnigi, 45 miles north of Napha, on the promontory of Fort Melville, we come to a coarse conglomerate, which gives us the first promise of a possibility of coal. The conglomerate soon passes into a coarse, and then into a finer sandstone. The slate and sandstone continue as we

advance northwardly, and at 7 miles from Farnigi, or 62 miles from Napha, we come to some outcroppings of the black bituminous slate, &c."

Furet has studied the fossils in the limestone and clay in the southern part of Okinawa-jima (Die Physikalischen Verhältnisse der Lutschu-Inseln.—*Petermanns Mittheilungen*, 1860, p. 156) and found in the limestone near Napha (Naha) and Tkiatung (?) the following eleven species:

Hemicidaris sp.	*Pecten aequivalvis,*
Pecten sp,	*Pecten quinquicostatus !,*
Pholadomia sp.	*Isocardium sp,*
Perna sp !,	*Terebratula oborata,*
Avicula sp !.	*Cerithium nudum,*
Fusus sp.	

He also mentions the following nine species as taken from the clay in the south of Napha:

Oliva clavula,	*Natica cepacea,*
Pectunculus aequivalvis,	*Ostrea flabelloides,*
Arca sp,	*Fusus neocomiensis,*
Spondylus sp,	*Plicatula sp,*
Ostrea marshii.	

He seems therefore to have regarded the formation as belonging to the upper part of the Mesozoic group.

A long time after the publication of the above two works, Prof. Döderlein* in 1880 made a two-weeks trip to Ōshima (in the Ōshima group). He started from Nase on the west coast on August 16th, and first travelled on foot through the island over Yuwan, Nagara and Kuji, following the shortest route. He then passed over to the next island,

* Die Liukiu-Inseln Amami Ōshima.—*Mittheilungen der deutschen Gesellschaft für Natur—und Völkerkunde Ostasiens.* Bd. III, 1880—1884, p. 103.

Kakeroma-jima, where he stayed a week on account of bad weather, and returned to Koniya in Ōshima. Then he went through Akina, Ichi, Gusuku and Asato, and returned to Nase on August 30th. According to his observations, the island consists of Archean rocks, which are chiefly granulite and gneiss. Only a small exposure of granite was found. There was also a bluish black clay slate at Cape Isisaki near Ichi, and a thin horizontal bed of recent (?) conglomerate at the harbour of Nase. He also explained the double-row structure of the islands in the *northern part* of the sea between Formosa and Kyūshū. The outer row including Tanega-shima, Yaku-shima, Amami-Oshima, Tokuno-shima and Okinawa-jima is sedimentary, while the inner row consisting of Kume-jima, Tori-shima, Linschoten, Erabu-jima, Kose-jima, Yuo-jima and Tage-shima is entirely volcanic. This was mentioned by E. Suess in his "Antlitz der Erde, Bd. II., 1888, p. 219;" and he remarked that the Riukiu Group might possess the same structure as the Antilles, Banda, Nicobar and Andaman.

With the exception of the above mentioned authors, I have failed to find any foreign geological observers, who have studied the geology of the Riukiu Curve. The islands have not been much visited on account of their lack of facilities for travel in their interiors, and also because of the presence of dangerous snakes and fevers. A very rough geological note with a map of the two groups, Okinawa and Sakishima, was published by Mr. T. Kada in "*The Journal of the Tōkio Geographical Society*, 7th year, No. 5, 1885." A brief topography of the same islands has been written by Messrs. Kuroiwa and Nakayoshi. Mr. Kuroiwa's "General Geological Observations in Kume-jima and Ishigaki-jima" is found in "*The Journal of the Geological Society of Tōkyō*, Vol. V. No. 59, 1898 and Vol. VII, No. 71, 1899"; that of Tanega-shima and Yakushima by Mr. Nishiwada in "*The Journal of Geography, published by the Tōkyō Geographical Society*, Vol VII, No. 81,

1895." Summarizing the results of the above mentioned works together with several others, Prof. Kotô made a description of the geotectonics in his "Geological Structure of the Riukiu Curve" (*Journ. Geol. Soc. Tōkyō*, Vol V. No. 49, 1897). He found in this curve *three* parallel rows of islands. The inner row, being the same as that of Döderlein consists entirely of neovolcanic rocks. In the middle row, of Palæozoic or older rocks, are found Yaku-shima, Ōshima, Okinawa-jima, Ishigaki-jima and Iriomote-jima, besides other small islands. The outer row, of Tertiary and Quaternary sediments, is found by the following islands, viz., Tanega-shima, Mage-shima, the southern part of Okinawa-jima, the islands lying east of Okinawa, and finally Iriomote-jima and Yonaguni-jima. According to Prof. Kotô, the characteristic arrangement of the rocks is probably due to the great depression of Tunghai (the "Eastern Sea" of China), and a curved fissure extending for several hundred miles between Kyūshū and Formosa.

On the north of Formosa and far to the north-west of the Yaeyama subgroup, there lie a few small, barren and uninhabited islands. Among them the Pinnacle group, consisting of Waheizan or Chōgyotō* (Hoa-pin-su), Kōbitō (Chia-u-su), Pinnacle and Raleigh rocks, belongs to the Okinawa Prefecture. The hydrographical as well as topographical survey of these islands has been made by many foreign and Japanese ships. Recently Messrs. M. Miyajima and T. Kuroiwa have reported respecting their situation, topographical features, &c. in "*The Journal of Geography*, *Tōkyō*, Vol. XII, No. 141, 1900 and Vol. XII, No. 144, 1900." Other islands lying nearer to Formosa are Agincourt Is., Crag Is. and Pinnacle Is. A rough geological and topographical note of these islands is found in "The China Sea Directory, Vol. III, 1894." Mr. Y. Saitō has visited the Crag and

* Among Japanese, the two names Hoa-pin-su and Chia-u-su have been confused and the Chinese characters 釣魚嶼 are incorrectly read Hoa-pin-su and 黄尾嶼 Chia-u-su.

Pinnacle islands† and found them to be entirely basaltic andesite. In Crag Is. the andesite is found in the form of lavas, dykes, ashes and breccias. According to the petrographic examination by Prof. Kotô, Agincourt Is. has hypersthene-basalt and hypersthene-andesite.

As to the geology of Formosa we have a number of notes. The coal-mines are mentioned in the following:—

Gordon, Observations on Coal in the N.E. part of the Island of Formosa—*Journal Roy. Geogr. Soc.*, Vol XIX, 1849, p. 22).

Jones, Report made to Commodore Perry of a visit to the Coal Regions of the Island of Formosa.—Narrative of the Exped. of an Amer. Squadron to the China Seas and Japan &c. Vol. II, 1856, p. 153.

Tyzack, Notes on the Coal-field and Coal-mining Operations in N. Formosa.—*Trans. North of Engl. Institute of Mining and Mechanical Engineering*, Vol. XXXIV, 1884, p. 67.

The geology of the neighborhood of Kōbi and Kiirun is in

Richthofen, Über den Gebirgsbau an der Nordküste von Formosa. —*Zeitschr. Deutsch. Gesell.*, XII Band, 1860, p. 532.

The determination of the age of the sediments of the neighborhood of Kiirun, by the fossils collected by Tyzack, is found in

Lebour, Notes on some Fossils from N. Formosa.—*Trans. North of Engl. Institute of Mining and Mechanical Engineering*, Vol. XXXIV, 1884, p. 67.

The principal facts gathered from these authors are as follows : There are, besides the Liassic deposit, two Tertiary formations, probably different in age. The older one with characteristic *Echinodiscus* is Miocene, and consists of a bluish shale, with clay and finegrained brownish sandstone. Coal-seams, especially those near Kiirun, appear to extend from east to west. Fossils found near Hokuto are *Ostrea*,

† 基隆沖無人島踏査報文 (Report on a Trip to the uninhabited Islands lying off the coast of Kiirun, 1900., *in Japanese*).

Lutraria (?), *Cardium* (?) and *Echinodiscus*. According to Richthofen, trachyte with its tuff and agglomerate, is found in the north-east and south-west of Kōbi, near Daiton-zan and Kwannon-zan ; and composes the foundation of the environs of Kōbi. Here a quite horizontal tuff predomates and forms the vast plateau onthe south-west of Kōbi. Porphyrite hills are found, according to Tyzack, at Daiton-zan and Kiirun-zan.

The more careful geological observations and microscopic studies by Japanese geologists, show these inferences to have been mostly incorrect. The igneous rocks of Daiton-zan, Kwannon-zan, Kiirun-zan and others, are proved to be not trachyte but andesite; and there has been found no trachyte tuff. The rocks of the vast plateau near Kōbi is nothing else than laterite.

Mr. Y. Ishii published in 1897 a reconnaisance map of Formosa with an explanatory text in Japanese.* Except the doubtful occurrence of gneiss, he found all the oldest rock to be crystalline schists, extending from the eastern side of Mount Sylvia up to the north-west of Pinan. A crystalline limestone, probably Palæozoic, is observed along the western side of this schistose belt, and extends from the east of Sessan to the north-west of Pinan. A clay slate of unknown age occupies a very wide area, between Tōi, north of Giran, and Bōryō near the southern end of Formosa. The main skeleton of the island, thus formed by the schists, limestone and clay slate, has been called the "Taiwan mountain system" by Mr. Ishii. The clay slate seems to surround the region of schists and limestone. The Tertiary sediments which overlie the clay slate without any discordance, are developed along the northern, western and southern sides of the principal range, as well as the middle of the eastern coast. Those in the northern part

* 台灣島地質鑛產圖說明書 (Explanatory Text to the Map of Formosa, showing Geology and Mineral Resources).

are composed of coarse-grained sandstones with shales, and contain many coal-seams and limestone layers. Raised coral reefs are found only near the southern end of the island, and are rather limited in extent; their formation appear to have continued from the Tertiary up to the Recent time. Quaternary sediments usually without coral reefs compose the vast plateau along the whole western coast, which is about one-fourth as wide as the island itself. As to the igneous rocks, Mr. Ishii has found granite near Sessan, and diorite near Niitaka-yama (Mt. Morrison). The serpentine exposed on the north of Pinan and on the west coast of Kōtō island, is probably a metamorphosed Tertiary gabbro. Andesites are exposed: (1), on the northern end of Formosa, as at Daiton-zan, Kwannon-zan, Kiirun-zan and the adjacent hills; (2), on the eastern coast, near Shūkorankei and on the north of Pinan; and (3), on the islands of Kōtō and Kwashō, off the south-east coast. The numerous islands of the Hōko group are almost all basalt. In Formosa, all the strata, older than Quaternary, are steeply inclined, but the strike is almost always parallel to the longitudinal axis of the island. There have probably existed great fissures along the eastern side, running parallel to this axis; as is partly indicated by the occurrence of volcanic rocks on the islands of Kōtō and Kwashō and on the north of Pinan. Besides the general geological note, above summarized, Mr. Ishii has given in the same note many valuable descriptions of the mining products of the island.

Messrs. K. Inoue and S. Yokoyama have also written about the geology of Formosa. Recently Mr. Saitō has published his geological sketches of the Zuihō and Kinkwaseki mines, in which he mentiones that the two hills Kiirun-zan and Kinkwaseki-zan are formed of andesite dykes erupted through Tertiary sediments. Mr. R. Yamashita † has, under the direction of Mr. Saitō, examined a number of

† 台灣北部煤田 (Coal-seams in the north of Formosa, 1900; *in Japanese*).

coal-seams, their relations, and various profiles of Tertiary rocks.

All the above works have been specially consulted in writing this paper. There are, besides, notes by the foreign writers. Corner, Guppy, Beazeley and Kleinwächter. giving the results of their observations chiefly in the region south of Takao; also the reports by the Japanese geologists, Prof. Kotô, and Messrs. Ishii, Inoue and Saitō. In Prof. Kotô's work,* there are very valuable petrographical notes on the Hōko group and the Kwashō and Kōtō islands. Mr. S. Yamasaki, who has travelled with Prof. Kotô, has also written about our present knowledge of the island in "*Petermann's Mittheilungen*, XLVI Band, 1900, X. p. 22." § Prof. J. Rein also spoke ‡ upon the same subject at the 'Niederrheinischen Gesellschaft für Naturkunde zu Bonn.'

PART III.—Geology of the Islands in the Riukiu Curve.

The Riukiu Curve consists of many groups of islands. Counting from the southern end, we have those of Saki-shima, Okinawa and Ōshima; then a row of small islands, collectively called Tokara and lying on the north-west of Ōshima; and finally the Ōsumi group with a few islands (such as Yaku-shima and Tanega-shima) between Tokara and Kyūshū.

I. THE ŌSHIMA GROUP.

This group includes Ōshima, with its numerous dependent islets, Kakeroma-jima, Edato-jima, Ikeji-jima, Yoro-jima, Sukomo-banare,

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* Notes on the Geology of the dependent Isles of Taiwan.—*Jour. Coll. Sci. Imp. Unv., Tōkyō*, Vol. XIII, Part. I, 1899, p. 1.

§ Ueber geographischen Kenntnisse von der Insel Taiwan (Formosa).

‡ Die physische Geographie von Taiwan (Formosa).—*Sitzungsberichte der Niederrheinischen Gessell. für Natur-und Heilkunde zu Bonn*, 1900, I Heft, p. A. 21.

Yū-banare, Eniya-banare, Kerama-jima and Hashiya-jima, and also Kikaiga-shima, Tokuno-shima, Okinoerabu-jima and Yoron-jima.

Ōshima and its Dependent Islets. Ōshima, one of the largest islands in the Riukiu Curve, has a great many indentations in its coast which is about two hundred miles in length. The interior is entirely mountainous except on the small northern peninsula. There are inhabitants only on this flat part and on the small plains at the openings of river valleys. The highest peak, Yuwan-dake is near Yuwan in the southern part and has an elevation of 2300 ft. The northern half of the island is elongated parallel to the trend of its principal hill-range which runs NE to SW. But in the southern half, the ranges are transverse to the length of the island. There are two remarkable parallel ridges in the western part running eastward, one from Sokkō-zaki, and the other from Edato-jima. They are separated by a very narrow inlet opening toward the west. The island of Kakeroma, on the south of the island of Ōshima, is also elongated parallel to these two ranges. The narrow channel between the last two islands is called Ōshima-kaikyō or Setouchi. The sea around Ōshima and the adjacent islands is very deep and there are many good anchorages.

All these islands are almost wholly composed of Palæozoic sediments, with very limited occurrences of old eruptives. Raised coral reefs, with intervening sandy layers, occupy only small areas in the northern corner of Ōshima.* The Palæozoic rocks are chiefly clay slate and sandstone, while slaty sandstone is also common. Tuff-pyroxenite with amphibolite was rarely observed in the island of Ōshima. Compared with the island of Ōkinawa, which also consists chiefly of Palæozoic rocks, we find a great resemblance in tectonic and petrography; but in the latter the pyroxenite

* Yoshiwara, Notes on the Raised Coral Reefs in the Islands of the Riukiu Curve.—*Journ. Coll. Sci. Imp. Univ., Tōkyō*, Vol. XVI, Art 1, 1901.

or amphibolite is more extensive, though it is only next to clay slate and sandstone in distribution. The sandstone of the island of Ōshima is often highly siliceous, thus taking the appearance of quartzite. A very compact, white or red quartzite occupies large areas in the island, though restricted to the western part. Schalstein, associated either with compact quartzite or with other rocks, is found on the road form Toen to Naon, Konase to Atetsu, Shodon to Nomisan, Akitoku to Osai, Setake to Kuji, Naze to Aira, Yanyū to Akaoki, Aira to Ikuzato, and south of Yamatohama; it is of very small extent and is always destitute of fossils. Palæozoic limestone is not rare; it is found in thick layers between Imazato and Uken, and in small lenticular masses in other rocks at Yui, Sokkō-zaki, Adachi and Sukomo, and near Setake and Yamma. The limestone is all crystalline and without fossils. The following is an abstract of my field note, showing the general stratification of the Palæozoic rocks :

Ōshima.

	Strike.	Dip.	Kinds of rocks.
From Naze to Koshiku.			
Naze—Asani	N—S	W 25	Slaty sandstone.
	N 20 E	N W 30	"
	N 30 E	N W 35	Quartzose sandstone with a little slate.
	N 40 E	N W 50	"
	N 40 E	N W 20	"
Asani—Koshiku	N 40 E	N W 20	Chiefly sandstone.
From Koshiku to Yamatohama.			
Koshiku—Chinase	N—S	W 30	Slate.
	N 40 E	N W 45	Sandstone.
Chinase—Yuwangama	N 20 W	S W 30	Chiefly slate.
	N—S	W 50	Slate and sandstone.
Yuwangama—Yamatohama	N 20 E	N W 45	"
	N 20 E	N W 70	"
From Yamatohama to Uken.			
	N 60 E	N W 25	Slate and quartzose sandstone.
Yamatohama—Ōdana	N 40 E	N W 25	"
	N 60 E	N W 40	"
Ōdana—Toen	variable, but never inclined toward E.		Slate and compact quartzite.
Toen—Naon	N—S	W 25	Schalstein.
	N 10 E	N W 40	Compact quartzite.
	N—S	W 40	"
Naon—Shitokan	N 30 E	N W 40	"
	N—S	W 30	"
			Porphyrite dyke.
	N 30 E	N W 35–55	Compact quartzite with thin layers of slate.
Imazato—Uken	variable		Limestone with thin layers of slate and compact quartzite.
	N—S	W 30	Slate.
From Uken to Yuwan.			
Uken—Kuji	variable		Slate and sandstone.
Kuji—Ikegachi	N 40 E	N W 50	Slate.
	N—S	W 35	"
Ikegachi—Ashiken	N 30 E	N W 45	"
	variable		Compact quartzite.
	N 30 E	N W 30	Slate.
Ashiken—Taken	variable		Alternations of thin slate and sandstone.
Taken—Yuwan	variable		Sandstone.
	N 30 E	N W 40	Alternations of sandstone and slate.
From Yuwan to Yamatohama.	N—S	W 80	"
	N 40 E	N W 30	"
	N 30 E	N W 40	Compact quartzite with thin layers of slate and sandstone.
	N 40 E	NW 30	"
	N—S	W 30	"
	N 30 E	N W 40	"
	N—S	W 40	"
	N 50 E	N W 30	"
From Yamatohama to Nishinakama.			
	N 35 E	N W 40	Slate and sandstone.
	N 10 E	N W 60	"
	N—S	W 30	"

	Strike.	Dip.	Kinds of rocks.
			Schalstein,
	N 10 E	N W 40	Slate and sandstone.
	N 20 E	N W 25	,,
	N 40 E	N W 30	,,
	N 50 E	N W 20	,,
	N—S	W 40	,,
	N 10 E	N W 40	,,
	N 25 E	N W 45	,,
From Nishinakama to Yuwan.			
Nishinakama—Yakkachi	N 10 E	N W 55	Slate.
	N 40 E	N W 65	,,
	N 20 E	N W 45	,,
Yakkachi—Suko	N 40 E	N W 70	Quartzose sandstone.
	N 10 E	N W 55	Slate.
	N 30 E	O W 55	,,
	N—S	W 30—65	,,
	N 30 E	N W 40	,,
Suko—Yuwan	N 40 E	S E 50	Alternations of thin slate and quartzose sandstone.
From Yuwan to Yadon.			
Suko—Buren	N—S	W 45	Sandstone and quartzose sandstone.
	N 20 E	S E 50	,,
Buren—Nagara	N 50 E	N W 35-65	,,
	N 50 E	S E 40	,,
	N 50 E	N W 45	,,
Nagara—Sanen	N 40 E	N W 55	Slaty sandstone.
Sunen—Heta	N 40 E	N W 30-45	Slate.
	variable		Compact quartzite.
	N 40 E	N W 60	Slate, quartzose sandstone and quartzite.
Heta—Amuro			Quartzose sandstone.
Amuro—Yadon	variable		Compact quartzite with very little limestone.
From Yadon to Nishikomi.	N 40 E	N W 40	Compact quartzite with a little slate.
From Nishikomi to Sokkō-zaki.	N—S	W 40	Quartzose sandstone and slate.
	variable		Compact quartzite with very little slate and quartzose sandstone.
From Nishikomi to Kuji.			Limestone.
Nishikomi—Kudadon	variable		Alternations of compact quartzite, slate and sandstone.
	N—S	W 40	Pyroxenite.
	N 40 W	S W 40	,,
Kudadon—Keten	N—S	W 40—45	Slate and quartzose sandstone.
Keten—Kuji	N—S	W 40	Sandstone.
From Kuji to Koniya.			
Kuji—Koshi	N—S	W 40	Sandstone.
	variable		Slate and bluish sandstone.
Koshi—Shinokawa	N 20 E	N W 50	Slate.
	N 40 E	N W 35	Alternations of thin slate and quartzose sandstone.
	N—S	W 30	,, ,, ,,
Shinokawa—Amurogama	N—S	W 35	,, ,, ,,
Amurogama—Konase	N 30 E	N W 40	Slate, quartzose sandstone and bluish sandstone.
	N 40 E	N W 40	,, ,, ,,
	N 30 E	N W 50	,, ,, ,,
Konase—Atetsu			Schalstein.
	N—S	E 40	Bluish sandstone.
	N—S	W 40	,,
	N—S	E 40	,,

	Strike.	Dip.	Kinds of rocks.
Atetsu—Yui	N 10 E	N W 45	Bluish sandstone.
	N 70 W	N E 35	Quartzose sandstone.
	N 60 W	N E 35	Alternations of sandstone and slate.
Yui—Kunezu	N 50 W	N E 50	Limestone with a little compact quartzite.
	N—S	W 50	Sandstone and slate.
	N 50 E	N W 30	,,
	N 40 E	N W 30-45	Slate.
Kunezu—Tean	N—S	W 70	,,
	N 30 E	N W 50	Slate, sandstone and quartzose sandstone.
Tean—Koniya	N 40 E	N W 40	,, ,, ,,
	N 10 E	N W 30	,, ,, ,,
	N—S	W 40	,, ,, ,,
	N 20 E	S E 20	,, ,, ,,
From Koniya to Akina (along the sea).			
Koniya—Seisu	N 40 E	S E 50	Sandstone.
	N 30 E	S E 55	Quartzose sandstone.
	N 60 E	vertical	Compact quartzite.
	N 10 E	S E 75	Sandstone and quartzose sandstone.
Seisu—Katetsu	N 50 W	S W 20	Sandstone and slaty sandstone.
Katetsu—Isu	N 10 E	N W 60	Quartzose sandstone.
			Sandstone.
	N 30 E	N W 40	Sandstone, quartzose sandstone and slate.
Isu—Akina	N 30 E	vertical	,, ,, ,,
	N 40 E	N W 80	,, ,, ,,
	N 30 E	N W 30	,, ,, ,,
From Akina to Sekko			
Akina—Katsuura	N 30 E	N W 45	Alternations of slate and quartzose sandstone.
Katsuura—Aminoko	N 20 E	N W 55	Slate with a little quartzose sandstone.
			Slate.
			Compact quartzite.
	N—S	W 45-80	Slate.
			Quartzose sandstone.
From Akina to Yamma			
Katsuura—Yakkachi	N 20 E	N W 40	Quartzose sandstone.
	N 10 E	N W 30	Alternations of slate and quartzose sandstone.
	N—S	W 30	Quartzose sandstone.
	N 30 E	N W 40	,,
	N—S	W 40	Slate.
Yakkachi—Yamma	N 30 E	N W 40	,,
	N—S	W 30	,,
	N 20 E	N W 50	Alternations of quartzose sandstone and slate.
From Yamma to Katoku			Quartzite and quartzose sandstone.
	N—S	W 55	Slate.
	N—S	W 70-80	Alternations of quartzose sandstone and slate.
From Katoku to Ichi			
Katoku—Ao	N—S	W 50	Slate.
			Quartzose sandstone.
	N—S	W 60	Slate.
	N 20 W	S W 55	,,
			Quartzose sandstone.
	N 20 E	N W 80	Slate.
	N 20 W	S W 50-60	,,
			Quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
Ao—Ichi	N 30 E	N W 35	Quartzose sandstone. Quartzite. Granite.
From Ichi to Yamma			
Ichi—Todama			Granite. Quartzose sandstone and quartzite.
Todama—Yamma	N 20-30 E	N W 35-65	Quartzite. Alternations of slate and quartzose sandstone.
From Yamma to Nishinakama			
Yakkachi—Nishinakama	N 20 E	N W 40	Quartzose sandstone and slate.
From Nishinakama to Gusuku			
Nishinakama—Higanakama	N 10 E	N W 35	Alternations of slate and quartzose sandstone.
	N 40 E	N W 20	,,
	N—S	N W 35	,,
	N 10 E	N W 65	Bluish sandstone.
	N—S	W 25	,,
	N 30 E	N W 60	,,
	N—S	W 45	,,
Higanakama—Gusuku			Slate, quartzose sandstone and bluish sandstone.
From Gusuku to Kominato.			
Gusuku—Nishinakagachi	N 20-30 E	N W 20-55	Alternations of slate and quartzose sandstone.
Nishinakagachi—Kominato	N—S	W 35	Alternations of slate, quartzose sandstone and bluish sandstone.
From Kominato to Ōgachi.			
Kominato—Toguchi	N 30-40 E	N W 25	Alternations of slate, sandstone and bluish sandstone.
	E—W	N 40	
	N 70 E	N W 30	
	N 60 E	N W 60	
	N 40 E	N W 40	
	N 20 E	S E 20	
	N 30 W	N E 35	
	N 20 W	S W 5	
	E—W	N 30	
	N—S	W 50	
	N 30 W	S W 30	
Toguchi—Ōgachi	N 30 W	S W 60	Slate.
	N 20 E	N W 50	,,
From Ōgachi to Akaoki			
	N—S	E 35	Alternations of quartzose sandstone and slate.
	E—W	N 35	,, ,, ,,
	N 10-20 E	N W 35-50	,, ,, ,,
From Akaoki to Tekebu.			
Akaoki—Kise	N 30 E	N W 30	Alternations of slate, quartzose sandstone and bluish sandstone.
	N—S	W 35-80	,, ,, ,,
	N 10 E	N W 80	,, ,, ,,
	N—S	W 50	,, ,, ,,
Kise—Tekebu			Quartzose sandstone.
From Akakina to Kasari.			
Akakina—Kawakami	N 20 E	N W 55	Quartzose sandstone and slate.
	N 40 E	N W 50	,,
	N 20 E	N W 40	Slate.
	N—S	W 55	,,
			Schalstein.

	Strike.	Dip.	Kinds of rocks.
Kawakami—Yani	N 20 E	N W 25	Slate.
Yani—Kutsuno	N 30 E	N W 25	,,
			Quartzose sandstone.
Kutsuno—Sani			,,
	N 30 E	N W 30	Slate.
			,,
Sani—Yō	N 70 E	N W 30	Alternations of slate and quartzose sandstone.
From Kasari to Akaoki.			
Kasari—Beru			Quartzose sandstone.
Beru—Suno	N 20 E	N W 65	,,
Suno—Ushuku	N—S	W 55	Quartzose sandstone, slate and quartzite.
	N—S	E 60	Quartzose sandstone.
Banya—Setta	N 30 E	N W 70	,,
	N 40 E	S E 40	,,
Setta—Yoan	N 30 E	N W 40	Alternations of sandstone, quartzose sandstone and slate.
			Diorite.
	N—S	W 70	Slate.
Yoan—Akaoki	N 20 E	N W 60	Quartzose sandstone with a little slate.
	N 10 E	N W 50	,, ,, ,,
From Akaoki to Tatsugō.			
Akaoki—Ashitoku			Slate.
Ashitoku-Yaniu	N—S	E 30	
	N 10 W	N E 30	,,
			,,
	N—S	E 35	Slate with sandstone and quartzose sandstone.
	N 20–30 W	S W 40	,, ,, ,,
	N—S	W 40	,, ,, ,,
	N 20 E	N W 30–35	,, ,, ,,
	N 20 W	S W 30	Slate.
Yaniu—Sekerube	N 30 E	N W 50	Quartzose sandstone.
Sekerube—Kuba	N 40 E	N W 35	Slate with a little quartzose sandstone.
	N 20 E	N W 60	,, ,, ,,
Kuba—Tatsugō			Quartzite with slate.
From Tatsugō to Akina			
	N 30 E	N W 40	Slate with quartzose sandstone.
	E—W	N 35	,,
	N—S	W 45	,,
	N 20 E	N W 30	,,
	N 20 E	N W 30	Alternations of slate and quartzose sandstone.
From Akina to Daikuma			
Akina—Ashikebu			
			Slate.
			Schalstein.
	N 20 E	N W 30	Slate with a little quartzose sandstone.
			Quartzose sandstone.
			Slate.
Ashikebu—Aira	N—S	W 20	,,
			Schalstein.
Aira—Daikuma	N—S	W 50	Slate.
			Alternations of slate and quartzose sandstone.
	N 40 E	N W 50	Slate.
			Schalstein.

	Strike.	Dip.	Kinds of rocks.
From Daikuma to Naze.			
			Schalstein.
			Alternations of thin slate and quartzose sandstone.
			Schalstein.
	N 20 E	N W 50	Slate.
			Bluish sandstone and quartzite.
	N 20 E	N W 50	Slate.

Kakeroma-jima.

	Strike.	Dip.	Kinds of rocks.
From Oshikaku to Shodon			
Oshikaku—Kachiyoki			Slate.
	N—S	W 65	Alternations of slate and quartzose sandstone.
	N 20 E	N W 70	Slate.
	N—S	W 40–45	,,
	N 40 E	N W 50	Alternations of thin slate and quartzite.
	N 40 E	vertical	Slate.
Kochiyoki—Shokazu	N 50 E	N W 80	Bluish sandstone.
	N 50 E	N W 30	Slate.
	N—S	W 55	,,
	N 70 E	N W 50	Quartzose sandstone.
Shokazu—Ikema	N 40 E	N W 40–45	Slate.
	N 40 E	N W 40	Alternations of thin slate and quartzose sandstone.
Ikema—Doren	N 20 E	N W 70	Slate and quartzose sandstone.
	N 20–40 E	S E 30–60	,,
	N 40 W	S W 10	,,
	N 30 W	N E 60	,,
			Slate.
Doren—Shodon			Sandstone.
	N 30 W	N E 40	Slate.
	N 60 E	N W 45	Sandstone.
	N—S	W 40	,,
From Shodon to Akitoku			
	N 20 E	vertical	Slate and quartzose sandstone.
Shodon—Nomisan	N 20 E	N W 70	,,
	N 20 E	vertical	,,
	N 20–30 E	N W 70	Schalstein.
	N 30 E	N W 55	Slate.
	N 20 E	N W 45	,,
	N—S	W 35	Sandstone.
	N 30 E	N W 50	Bluish sandstone.
Nomisan—Akitoku			Slate.
	N 40 E	N W 30	Bluish sandstone.
			Quartzose sandstone.
From Akitoku to Nishiamuro			
			Schalstein.
Akitoku—Sachiyoki	N 40 E	N W 30	Slate.
	N 30 E	N W 35	,,
	N 50 E	N W 25	Quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
	N—S	W 40	,,
Sachiyoki—Osai	N 40 E	N W40	Quartzose sandstone and slate.
	N 60 E	N W 35	Quartzose sandstone.
	N 30 E	N W 45	Schalstein.
			Slate and quartzose sandstone.
	N 20 E	N W 50	Slate.
	N—S	W 40	,,
	N 20 E	N W 45	,,
Osai—Ikomo			Quartzose sandstone.
Ikomo—Kedomi	N—S	W 55	Slate and quartzose sandstone.
			Compact quartzite.
Ikomo—Nishiamuro	N 20 E	N W 30	Slate and quartzose sandstone.
			Compact quartzite.
	N 30 E	N W 55	Slate and quartzose sandstone.
From Nishiamuro to Shiba.			
	N 20 W	S W 30–45	Compact quartzite.
Nishiamuro—Kaniu			Slate.
	N 30 E	N W 50	Compact quartzite.
			,,
Kaniu—Sukomo	N 20 E	N W 60	Slate.
			Compact quartzite.
			Slate
			Compact quartzite.
	N—S	W 25	Limestone.
			Slate.
Sukomo—Adachi			Compact quartzite.
	N—S	W 35	Slate.
			Compact quartzite.
			Limestone.
Adachi—Saneku			Compact quartzite.
			Quartzose sandstone and slate.
			Compact quartzite.
			Bluish sandstone.
			Compact quartzite.
			Slate and quartzose sandstone.
			Compact quartzite.
	N—S	W 50	,,
Saneku—Shiba			Bluish sandstone.
	N 20 E	N W 45	Compact quartzite.
	N—S	W 45	Slate.
From Shiba to Satsukawa.	N 20 E	N W 45	Quartzose sandstone and slate.
From Satsukawa to Setake.	N 40 W	S W 50	Slate.
			Compact quartzite.
	N 20 E	N W 60	
	N 10 W	S W 50	Slate.
	N 10 E	N W 40	,,
From Setake to Oshikaku.			
			Limestone.
Setake—Kiji			Slate.
			Schalstein.
			Quartzose sandstone.
			Slate.
	N 40 E	N W 50	Quartzose sandstone.
			Compact quartzite.
Kiji—Takena			Slate.
	N—S	W 45	Compact quartzite.
Takena—Miura	N—S	W 35–45	Slate.
Miura—Hyō	N 30 E	N W 60	Alternations of slate and quartzose sandstone.
			compact quartzite.
	N 20 E	N W 55	Slate and quartzite sandstone.

	Strike.	Dip.	Kinds of rocks.
Hyō—Sesō	N 20 E	N W 60	Compact quartzite. Quartzose sandstone and slate.
Sesō—Oshikaku	N 20 E	N W 20	Compact quartzite. Slate and quartzose sandstone.

As shown in the abstract of my field notes, all the rocks dip steeply westward and are never horizontal. The strike is NE to SW which is nearly parallel to the line connecting the island of Ōshima with Tokuno-shima and Yoron-jima. The whole interior of the first island is mountainous; there is a plateau only on the northern end, which has been denuded and partially covered with raised coral reefs. A long narrow inlet with deep water, lying on the south of Edato-jima, is probably due to the formation of a fissure, perpendicular to the axis of the Ōshima group. There are greatly contorted strata as well as porphyrite eruptions on both sides of the inlet. The narrow and deep channel between Ōshima and Kakeroma-jima, probably of a similar origin, extends in the same direction as this inlet, and there is another porphyrite dyke on the northern coast of the western part. Besides the above mentioned three parallel dykes, exposed at Uken, Kuji, Ikegachi, Ashiken, Buren, Nagara, Sanen, Kudadon and Keten, there are three other dykes of the same porphyrite running generally NE—SW. They are found in Kakeroma-jima and on the road from Nagara to Keten in Ōshima. That exposed on the south of Naon is properly hornblende-porphyrite. No volcanic rocks are found in the islands; pre-tertiary eruptives are exposed chiefly near the eastern coast. Biotite-granite is found to have been erupted through the Palæozoic rocks near Yamma, as at Ichi, Todama and other villages. Diorite with a little granite is found near Tekebu on the northern corner of Ōshima.

Tokuno-shima. This island is elongated from north to south.

The high mountains in the interior consisting of Palæozoic rocks and plutonics, are surrounded by a vast plateau of Diluvial reefs, which is especially extensive in the southern part. The highest peak is Inokawa-dake which rises 2207 ft. above the sea-level. The Palæozoic rocks are chiefly clay slate, the same as that in Ōshima. Sandstone and quartzose sandstone are not uncommon, but pyroxenite or amphibolite is rarely found. Compact quartzite was never observed even in the form of fragments. All these rocks are regularly folded, but show several disturbances in contact with the plutonics.

	Strike.	Dip.	Kinds of rocks.
From Sanmura to Ketoku			
	N 30 E	N W 25	Slate.
	N—S	W 30	"
	N 30 E	N W 25	"
	N 20 E	N W 40	"
			Sandstone and pyroxenite.
	N 40 E	N W 30	Slate.
From Ketoku to Bumo			
			Slate.
			Quartzite.
	N 40 E	N W 60	Slate.
	N—S	W 30	"
	N 20 E	N W 55	Slate with a little quartzose sandstone.
	N—S	W 45	"
From Shimokushi to Inokawa			Slate and sandstone.
From Kamezu to Omonawa	N 40 W	S W 40	Slate, sandstone and quartzose sandstone.
	N 20 W	S W 30-50	"
Intabu-dake	N—S	W 30	Qartzite with a little slate.
From Shirai to Kamezu	N—S	W 30	Bluish sandstone and slate.
	N 40 E	N W 35	Slate.
From Kamezu to Mikyō	N—S	W 30	Bluish quartzose sandstone.
	N 20 E	N W 20	Slate.
			Serpentine.
	N 50 E	N W 40	Quartzose sandstone.
			Granite.
	N 50 E	N W 50	Quartzose sandstone and slate.
From Tōbe to Ketoku	N—S	W 30	Quartzose sandstone.
From Matsubara to Sanmura			
	N 40 E	N W 80	Greywacke sandstone.
Matsubara—Yonama	N 30 E	N W 60	Slate.
			Quartzose sandstone.
	N 30 E	N W 40	Slate.
	N 40 E	N W 45	"
Tete—Kanami	N 60 E	N W 55	Quartzose sandstone.
	N 40 E	N W 55	Slate and quartzose sandstone.

	Strike.	Dip.	Kinds of rocks.
Kanami—Sanmura	N 60 E	N W 40	Slate and quartzose sandstone.
	N 40 E	N W 45	,,
	N 50 E	N W 35	,,
	N 60 E	N W 55	,,
	N 70 E	N W 50	,,
Amekidake	N 40 E	N W 30	Slate and quartzite.

The above list shows that, the general dip is NW and the strike NE to SW, as in Ōshima.

In the plutonics, there are various granites in different places, *e.g.*, I found biotite-granite at San-mura and hornblende-granite on the road from Mikyō to Kamezu. Diorite is exposed over large areas, together with granite in the vicinity of Buma. Serpentines are found in some places, *e.g.* near Mikyō. Dyke rocks are not uncommon; quartz-porphyry is found on the west of Buma, at Shimokushi and Inokawa, and between Inokawa and Shoda, Yaezao and Shirai, Mikyō and Setaki. On the north of Ketoku, there is a porphyrite dyke with a strike N45°E. These pre-tertiary igneous rocks have disturbed, only at the line of direct contact, the Palæozoic strata which usually show regular dips. Thus the last tectonic disturbances in Tokuno-shima, Ōshima and other islands seem to have taken place long after their eruption, and certainly before the elevation of the reefs which are quite horizontal.

Okinoerabu-jima. This island is a table-land of Diluvial coral reefs with two peaks of Palæozoic rocks in the interior. The highest peak Ōyama has a height of only 687ft. above the sea-level. The island extends from NE to SW, which is also the direction of the axis of folding of the Palæozoic rocks. In the bluish quartzose sandstone of Ōyama, I have found the following stratifications:—

N30°E NW20° N45°E NW30° N—S W30°

The Palæozoic on the north-east of Ōyama is chiefly clay slate. In the eastern part of this region, a Palæozoic sandstone is pierced by a porphyrite dyke with a NE strike.

Yoron-jima. Though I have not visited this island, I am informed that it is very low and plateau-like, consisting mainly of raised coral reefs. As judged from a collection of rocks, there are in the interior limited exposures of Palæozoics, such as pyroxenite, sandstone and limestone.

Kikaiga-shima. This small island with a coast line of about 20 miles lies far to the east of Ōshima and Tokuno-shima. The longitudinal axis runs NE to SW, parallel to a line joining Ōshima with Yoron-jima. The interior is a flat table-land, with a maximum height of 684 ft. above the sea-level. The coast is cliffy and fringed with recent coral reefs. The island consists of raised coral reefs with a foundation of Tertiary rocks which are exposed only in a cliff near the sea coast (Fig. 1). The Tertiary rocks on the eastern coast, traceable

Fig. 1.—A view of Kikaiga-shima, as seen from the south-east.

from Sōmachi to Kamikatetsu, are chiefly bluish sandy shale, often with intervening layers of marls and loose brownish sandstones and very rarely with thin pumice beds. The sandy shale on the road from Keraji to Urabaru shows a strike N20°W or N—S, and dip NE or E with an angle of 35°. In the western part of the island, there is found a marly sandstone, sometimes alternating with loose bluish sandstone, and always dipping due west 5°.

II. THE TOKARA GROUP.

This group lying on the north-west of Ōshima, consists of very small islands on a line NE to SW; viz, Yoko-shima, Kaminone-sho, Tokara-jima, Shimako-jima, Akuseki-jima, Suwanose-jima, Nakano-shima, Kuchino-shima, Taira-jima, Gwaja-jima and Kogwaja-jima. According to Mr. Yamagami, all these islands consist of andesite. Solfataras are said to exist on Nakano-shima, Kogwaja-jima and Akuseki-jima. He also informs me that Suwanose-jima is even now sending forth lava and is considered as the only active volcano in the Riukiu Curve. Besides, distinct volcanic craters are seen in Nakano-shima and Akuseki-jima, and some traces of volcanic centres in Kuchino-shima and Gwaja-jima.

III. THE ŌSUMI GROUP.

This group contains only a few scattered islands near Kyūshū. The two largest islands, Tanega-shima and Yaku-shima, have already been described by Mr. Nishiwada.* According to him, Tanega-shima has the shape of a battery with the highest peak 1200 ft. above the sea-level, and consists of Tertiary rocks, such as sandstone, shale and conglomerate, with thin layers of impure limestone and brown coal-seams. The strata are greatly distorted with a strike NNE, which is parallel to the longer axis of the island. Diluvial rocks cover the Tertiary, but here the raised coral reefs, which are met with in the islands lying to the south, are never found. According to Mr. E. Sagawa, who visited this island in 1899, the interior seems to be composed of two different formations. The older one is greatly

* 種子島及屋久島探險記 (Report on Tanega-shima and Yaku-shima; *in Japanese*).—*The Journal of Geography*, *Tōkyō*, Vol. VII, No. 80, 1895.

distorted, hard and slate-like, and is Tertiary or even older; while the other one is less distorted and has the aspect of a more recent Tertiary.

Yaku-shima is entirely destitute of flat land, and the highest peak has an elevation of 6345 ft. The central portion is entirely granite. Only around the coast do we find clay slate and sandstone, which are older than the granite, as in Ōshima, Tokuno-shima and other islands.

The island Make-jima lying near Tanega-shima is composed of Tertiary sediments. The four islands of neovolcanic rocks (andesites), Kuchinoerabu-jima, Kuro-shima, Iwō-jima and Take-shima, are situated on a line connecting the islands of the Tokara group with some volcanoes in Kyūshū, such as Kaimon-dake, Sakura-jima and Kirishima-yama. According to Mr. Yamagami Iwō-jima has a crater at the summit, which is now vigorously emitting sulphuretted hydrogen gas. Kuchinoerabu-jima has also a distinct crater which emits the same gas. In 1839, a great eruption took place in the latter island, and many persons were buried in the ejectamenta.

IV. THE OKINAWA GROUP.

Besides the main island, Okinawa, with its numerous dependent islets, such as Kudaka, Tsuken, Kouri, Miyagusuku, Ike, Ie, Sesoko, Minna, Yagaji, Ō, Shitomo and others, this group includes the islands of the Iheya subgroup (five in number), those of Kerama subgroup (more than twelve) and the islands of Kume, Tonaki, Aguni and Tori.

Okinawa-jima and its Dependent Islets. The principal part of Okinawajima trends from NE to SW, and the southern part from N to S. The former, being almost entirely Palæozoic, is mostly mountainous

especially near the northern part; the western coast is nearly straight, with the exception of the tongue-shaped projections of Motobu, Akamaruga-saki and Hedo. It is very interesting, that these regions which project out to sea are composed of Palæozoic sediments entirely different from those in other places. The highest peak Katsuo-dake, is found in the Motobu region and has an elevation of 1557 ft. above the sea-level. The southern part of Okinawa-jima is generally plateau-like, and belongs to the Tertiary and Post-tertiary formations.

The Palæozoic rocks are clay slate, sandstone, pyroxenite or amphibolite, and schalstein found in the main part of the island; and the overlying limestone with compact quartzite, found in the western part, viz. in the regions of Motobu, Akamaruga-saki, Hedo, and in the south of Shioya. In the region of Motobu the dip is variable, but most frequently west or south-west 20—70 degrees. Pl IV shows the kinds of rocks observed in my trip through this region. In the limestone with compact quartzite, belonging to the western part, there are thin layers of slate, sandstone and pyroxenite or amphibolite, all of which are also found in the main part. Moreover the limestone and compact quartzite are conformable with the same rocks in the main part and seem to represent only a later part of the same period as is shown by the dips. In the other islands of the Riukiu Curve, all of the Palæozoic rocks are also associated with one another. Thus in Ōshima, the two rocks showing generally a westward dip, are found in the western part and are often intercalated in the other Palæozoic rocks, just as in Okinawa-jima. Moreover the islands on the west of Okinawa, viz., Sesoko, Ie and Kouri, and those in the Iheya subgroup are almost all composed of limestone and compact quartzite and not of other rocks.

The following abstract of my note refers to the Palæozoic rocks lying outside of the Motobu region :

Okinawa-jima.

	Strike.	Dip.	Kinds of rocks.
From Kina to Onna.			
Kina—Yamada	N 50 E	N W 30	Slate.
	N 40 E	N W 50	,,
Yamada—Fuki	N 40 E	N W 50	,,
Fuki—Chatan	N 40 E	vertical	,,
Chatan—Onna			Quartzose sandstone and slate.
From Onna to Choda.			
Onna – Seragaki	N 50 E	N W 40	Pyroxenite with a little quartzose sandstone.
Seragaki—Afuso			Slate and quartzose sandstone.
Afuso—Nakama	N 30 E	N W 50	,,
			Porphyrite dyke.
	N 40 E	N W 50	Slate.
Nakama—Kise	N 40 E	N W 30	,,
Kise—Kōki	N 40 E	N W 40	,,
Kōki—Choda	N 40 E	N W 40	,,
From Choda to Nago.			
Choda—Sukuda			Slate.
			Porphyrite dyke.
			Hard sandstone.
	Distorted		Slate.
	N 50 W	S W 30	,,
Sukuda—Semurokei	N 10 W	S W 40	,,
	N 30 W	S W 30	,,
Semurokei—Nago	N 30 W	S W 45	Hard sandstone.
From Nago to Oyakawa.			
Nago—Izashigawa			Alternations of slate and sandstone.
From Oyakawa to Shioya.			
Inamine—Genga	N 40 E	N W 40	Quartzose sandstone.
Genga—Tsuwa	N—S	W 20	Pyroxenite.
			Porphyrite dyke.
Tsuwa—Tonujā			Slate.
Tonujā—Shioya			,,
From Shioya to Okuma.			
Shioya—Nejime			Quartzose sandstone.
Nejime—Ōgimi			,,
Ōgimi—Ōkaneku	E—W	S 20	Slate.
Ōkaneku—Nyōha	N 60 W	S W 30	,,
	N 40 E	N W 40	Limestone.
Nyōha—Hama	N 80 E	N W 20	,,
	N 20 W	S W 50	,,
Hama—Okuma	N 20 W	S W 20	,,
	N 20 E	N W 20	Slate.
	E—W	S 20	,,
From Okuma to Hetona.	N 50 W	S W 20	Quartzose sandstone with a little slate.
From Hetona to Yona.			
Hetona—Iji	N 60 W	S W 40	Quartzose sandstone.
Iji—Yona	N—S	W 40	Alternations of slate and sandstone.
From Yona to Shashiki.			Sandstone and porphyrite dyke.
From Shashiki to Henoki.	N 20 E	N W 20-50	Sandstone with very little slate.
From Henoki to Uka.	N 20 E	N W 30	Sandstone.
From Uka to Ginamabara.			
	N 30 W	S W 20	Sandstone with a little slate.
	N—S	W 40	,,
	N—S	W 45	Sandstone and slate.
Jachinbira	N 40 W	S W 45	,,
	N—S	W 30	,,

	Strike.	Dip.	Kinds of rocks.
Bumibira	N 40 E	N W 20-40	Quartzose sandstone with a little slate.
From Ginamabara to Hedō.	N 45 E	N W 40	Slate.
From Hedō to Oku.	N 40 E	N W 45	"
	N—S	W 40	"
From Oku to Sosu.			
	N 54 E	S E 30	Slate.
	N—S	W 50	Quartzose sandstone.
	N 40 E	N W 40	"
	N 50 E	N W 40	"
	N—S	W 30-70	"
	Distorted		"
	N—S	W 40-80	"
From Sosu to Ada.			
	N 20 E	N W 60	Slate.
	N—S	W 50-60	"
	N 20 W	S W 50	Quartzose sandstone.
	N 20 E	N W 50	Alternations of quartzose sandstone and slate.
	N—S	W 50	
	N—S	W 60	
	N 20 W	S W 50	
	N—S	W 50	
	N 10 W	S W 80	
	N—S	W 60	
	N 10 E	N W 80	
	N 10 E	N W 50	
From Ada to Awa.			
	N—S	W 50-70	Slate.
	N 10-20 E	N W 70	"
	N 10 W	S W 70	Quartzose sandstone.
From Awa to Miyagusuku.			
Awa—Arakawara	N—S	W 50	Quartzose sandstone and slate.
	N 40 E	N W 40	"
	N—S	W 40	"
	N 40 E	N W 50	"
	N—S	W 30	"
	N 30 E	N W 50	"
Arakawara—Miyagusuku	N—S	W 50	Slate.
	N 40 E	N W 50	"
	N 20 E	N W 50	Sandstone.
	N 20 E	N W 40	"
	N—S	W 50	"
	N 40 E	N W 40	Slate with a little sandstone.
	N 10 E	N W 50	"
	N 30 E	N W 50	"
	N—S	W 45	"
	N—S	W 60	"
	N—S	W 70	Sandstone.
	N 30 E	N W 50	Slate
From Miyagusuku to Arume.			
Miyagusuku—Kawada	N 20-40 E	N W 40-60	Sandstone with a little slate.
	N—S	W 40-60	"
Kawada—Tēra	N 30 E	N W 50	Slate.
Tēra—Kesaji	N 30 E	N W 20	Sandstone.
	N 40 E	N W 30-50	"
	N 40 E	N W 40	Slate.
Kesaji—Arume	N—S	W 50	"
	N 20 E	N W 70	"
	N—S	W 50	"
	N 30 E	N W 60	"

	Strike.	Dip.	Kinds of rocks.
From Arume to Setake.			
Arume—Teniya	N 50 E	N W 60	Sandstone and conglomerate.
	N 50 E	N W 50	Slate.
	N 60 E	N W 40	"
	N 70 E	N W 25	Sandstone.
	N 50 E	N W 30	"
Teniya—Kayō	N 70 E	N W 50	Sandstone.
	N 60 E	N W 40	Slate.
	N 80 E	N W 50	"
	N 60 E	N W 30	Sandstone.
	N 80 E	N W 40	"
Kayō—Abu	N 40 E	N W 15	Sandstone.
	N 30 E	N W 30	"
Abu—Tēma	E—W	N 50	Sandstone with a little slate.
	N 40 E	W 50	"
	N—S	W 50	"
	N 60 E	N W 50	"
	N 80 E	N W 50	"
Tēma—Setake	N 60 E	N W 60	Sandstone and slate.
From Setake to Ōura.	N 20 E	N W 50	Slate.
From Kushi to Kin.			
Kushi—Kochiya	N 60 E	N W 30	Slaty sandstone.
	N 50 E	N W 30	"
Kochiya—Kanna	variable.		"
Kanna—Kin	variable.		Slaty sandstone, schalstein, slate and sandstone.
From Kin to Ishikawa.			
Kin—Ige	N—S	W 50	Alternations of schalstein and quartzose sandstone.
	N 45 E	N W 70	Slate.
	N 30 E	N W 50	"
	N 70 E	N W 70	"
	N—S	W 30	"
	N 20 E	N W 30	Alternations of pyroxenite, quartzose sandstone and slate.
	N—S	W 30	" " "
Ige—Yaka	N 30 E	N W 40	Quartzose sandstone.
	N 50 E	N W 30	"
	N 50 E	N W 40	Pyroxenite with thin alternations of slate and quartzite.
Yaka—Ishikawa	N 40 E	N W 40	" " "

It is apparent, that Okinawa-jima is simply a continuation of Ōshima, which it closely resembles in tectonics and petrography. The Palæozoic rocks found in the former are never horizontal, and have the strike parallel to the longer axis of the island, and the dip almost always westward. There is observed no marked folding or faulting on the sea coast, nor in the interior. The principal Palæozoic rock is clay slate. Greywacke sandstone is also common. Pyroxenite or amphibolite is more extensive, and schalstein less so than in Ōshima.

Fossils are not found in these rocks. I was able to collect specimens of only a single species of coral from the limestone in Motobu, and of an indeterminable Mollusca from the same limestone bed in the neighbouring island of Sesoko.

The southern part of Okinawa-jima, which trends from N to S in contrast with the principal Palæozoic region, shows a foundation of Tertiary sediments. They were once entirely covered with raised coral reefs, but these now remain only in scattered patches. The Tertiary sediments are also exposed in the valleys of the Palæozoic regions near Oyakawa. The chief Tertiary rock is a loose sandy shale with thin layers of marl. Sandstones of a fine-grained brownish, and of a hard bluish calcareous variety are sometimes found at Toguchi near Ōse, and a bluish shale near Naha and Ōse. Fossil wood and a few species of small shells are found here and there in the sandy shale. I have collected at Kochinda *Leda*, *Drillia*, *Natica*, *Dentalium octogonum* Lamk. and one other species of the last mentioned genus. A number of Foraminifera, belonging to *Operculina*, which is small in size and not identical with the characteristic species found in Diluvial reefs in the Riukiu Curve, have been gathered from the loose sandstone in Okinaga near Itoman. The Tertiary rocks are either quite horizontal, or inclined in various directions in contrast with the regularly bedded Palæozoic; as

at Naha	E—W N10,° or N60°E NW50°
at Taira near Shuri	N30°E NW20°
at Nakanishi (north of Naha)	horizontal
on the road from Shuri to Konaha	N60°E NW40,° N60°E NW10°, N50°W SW50°
at Konaha	N40°E SE35°
on the west of Yonabaru	horizontal
at Ōse	N45°W NE5°
at Okinaga	N40°E NW20°

at Kochinda	N40°E	SE10°		
on the road from Kochinda to Hēbara	N60°W	SW25,°	N-S	W15,°
	N40°W	SW10°		
near Oyakawa	N40°E	SE20°		

The igneous rocks are all Pre-tertiary porphyrite forming eight dykes, all in the western part of the island. With a single exception at Nakama on the east of Onna, where it is N30°W, the strike of the dykes is parallel to the long axis of the island. The fifth dyke, counting from the west, runs exactly along the western coast on the north of the Motobu region. The dykes mostly belong to the mica-porphyrite, and there is no hornblende-porphyrite as in the vicinity of Naon in Ōshima. All the dykes pierce the Palæozoic rocks, but never come in contact with the Tertiary.

Yagaji-jima is merely a piece of land separated from Okinawa-jima by the action of the sea. The Palæozoic limestone with compact quartzite is nothing but a continuation of that in the Motobu region; and the clay slate and sandstone in the center of Yagaji-jima are the same as those in the principal part of the larger island. The remaining parts are almost wholly occupied by raised coral reefs. Only at the south-eastern corner there is a very small area of Tertiary sandstone with marl, exposed by the erosion of overlying reefs. This Tertiary rock contains fossil leaves, corals, *Dentalium*, *Tapes*, *Nassa*, and *Trochus*.

Kouri-jima, as well as Sesoko-jima, consists of Palæozoic limestone with a belt of raised coral reefs all around it. In the latter island, there is Palæozoic sandstone at the north-eastern and south-western ends of the limestone region. Some small exposures of compact quartzite are there found in different places. All these sediments incline to the west or north-west as in the case of the other islands. A dyke of porphyrite is traceable along the eastern side of

the limestone, and runs from NE to SW. Minna-jima lying near Sesoko-jima is a very flat island, composed wholly of coral reefs.

Ie-jima has a remarkable feature in a huge pointed rock called Gusuku which rises out of the surrounding hills in the eastern part of the island (Fig. 2). There is another point called Buppiji, but it is

Fig. 2.—View of Ie-jima seen from Tokuji.

only a little higher than the vast surrounding plateau, which is entirely made up of raised coral reefs. The rocks of these two prominences are compact quartzite and limestone, the same as those in the other islands of the Riukiu Curve. I collected a specimen of diabase exposed after the erosion of a reef. Blocks of Palæozoic sandstone and pyroxenite are found enclosed within the raised reefs. Though the latter are horizontal, the Palæozoic is always inclined with the strike NE and the dip NW, characteristic of the Riukiu Curve.

The above-mentioned small islands of the Okinawa group are all situated on the western side of Okinawa-jima. Those on the east of this island are arranged in a N—S line and are six in number; namely Ike, Miyagusuku. Hama (Fig. 3), Hianja (Fig. 4), Tsuken and Kudaka.

Fig. 3.—View of Hiama-jima seen from Yonagusuku-jima and Hianja-jima.

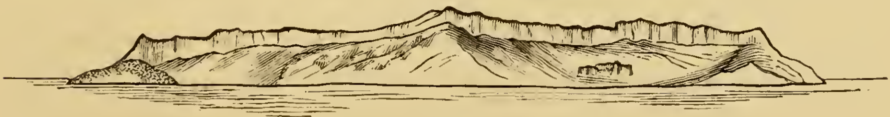


Fig. 4.—View of Hianja-jima seen from the western side of Yonagusuku-jima. (Tertiary rocks on the western [*i.e.* left] side).

They are all entirely capped with horizontal reefs. Only in Miyagusuku-jima and Hianja-jima, the foundation rock, raised above the sea-level, is loose brownish sandstone with intervening marly layers; bluish sandy shale also occurs. In Miyagusuku-jima they are inclined to SE on the south-eastern side; and to SW 10 degrees with the strike of S60°E, in the southern part. Fossils found from the Tertiary of this island are mostly small forms of shallow sea deposits. They are *Natica*, *Trochus*, *Guildfordia*, *Pectunculus*, *Limopsis*, *Pecten*, *Anomia* and *Dentalium*. There are also well preserved specimens of *Rhynchonella lucida* Gld., *Mergelia sanguinea* Chemn., *Terebratella mariae* A. Ad., *Terebratula japonica* Sow., *Dosinia exoleta* Linn'e and *Nucula mirabilis* Hinds. Besides these, I have collected unpetrified wood, fossil bones, corals and echinoids. The Tertiary rocks on the northern side of Hianja-jima, when traced from the western end of the island to the east, show a gradual change of dips, namely from an eastward to a southward and finally to a southwestward. Thus the structure, arrangement and kinds of the Tertiary rocks of the islands on the east of Okinawa-jima are just the same as those in the southern part of the large island itself, with which they are similar in origin.

Almost all of the *Kerama Subgroup* which contains the islands of Zamami, Aka, Geruma, Mokaraku, Yakashi, Kuba, Tokashiki, Kuro, Mae and others, as well as *Tonaki-jima* seems to consist of Palæozoic rocks. So far as I know, there is no trace of raised coral reefs; and the islands are mostly mountainous like the northern part of Okinawa-jima. Zamami-jima is especially mountainous and has the best anchorage of any of the Riukiu islands. Palæozoic slate, with a less extensive sandstone, generally dips toward the south, southwest or west, with an angle of 20°-45°, but never to the east, as in the other islands in Riukiu. A dyke of porphyrite is found in Akamura. Aka-jima, lying on the south of Zamami-jima, consists chiefly of greywacke

sandstone, often with slate. Pyroxenite or amphibolite is rarely found. These rocks show the same general dip as in Zamami-jima with an angle of 25°—45°. Geruma-jima and Mokaraku-jima are chiefly composed of sandstone and slate, showing the same dip as in the two islands above mentioned. Indeed the islands of the Kerama subgroup are nothing else than the mere continuation of the region of Palæozoic rocks, excluding compact quartzite and limestone, in Okinawa-jima, the evidence of which is assured by the kinds of rocks and the position of the islands on the map.

The *Iheya Subgroup* trending north and south, is composed of four small islands, Iheya, Gushichā, Izena and Yanaha. Mr. Kuroiwa has found most of these islands to be of compact quartzite, except Yanaha-jima and a part of Gushichā-jima, which consist of raised coral reefs.

The very small islets on the west of Naha, namely *Kei-jima Koisa-jima* and *Kisu-jima* consist essentially of fragments of recent reef corals. Only the western part of Kei-jima consists of undisturbed old reefs.

The three islands, *Kume*, *Aguni* and *Tori* are the only volcanic islands in the Okinawa group. Tori-shima, lying far to the northwest of Tokuno-shima, has a length of three miles, and is still emitting a great quantity of sulphuretted hydrogen gas. Mr. Kuroiwa has found Aguni-jima to be formed of neovolcanic rocks with raised coral reefs; and Kume-jima* to be almost entirely augite-andesite. Only between Janadō and Uemura on the eastern side of Kume-jima is there a little exposure of Tertiary (?) sandstone, dipping 45° to the northwest. A small mass of schalstein is found enclosed in the volcanic rock. Thick raised coral reefs are found also in this island, along its northern and on the middle of its western coast.

* 久米島 (Kume-jima; *in Japanese*).—*The Journ. Geol. Soc. Tōkyō*, Vol. V, No. 59, 1898.

V. THE SAKI-SHIMA GROUP.

The Saki-shima group is divisible into two subgroups, Miyako and Yaeyama, the former lying far to the east of the latter.

The Miyako Subgroup.

This subgroup contains the islands of Miyako, Shimoji, Irabu, Kurima, Ikema, Ōgami, Tarama and Minna (Fig. 5). Ōgami-jima alone consists of Tertiary calcareous sandstone with shale, surrounded by raised coral reefs; all the other islands are made up entirely of

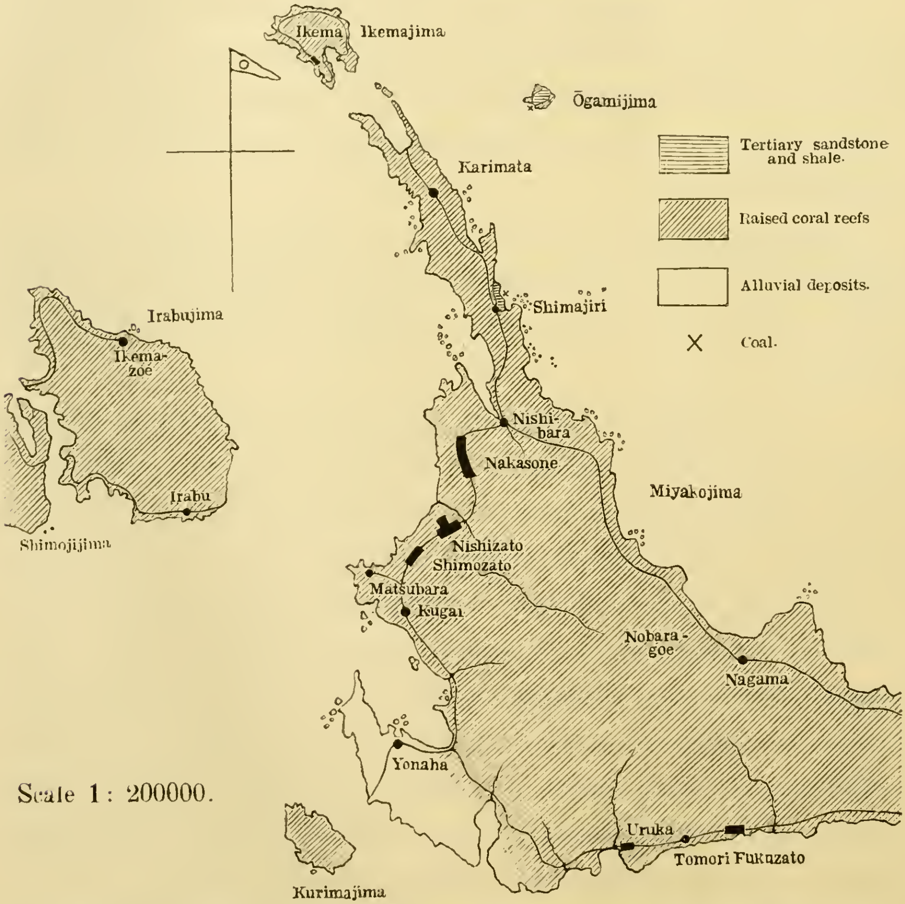


Fig. 5.—Geological Map of the Miyako Subgroup excluding Tarama-jima and Minna-jima.

raised reefs. Their Tertiary foundation is exposed only at Shimajiri on the north-eastern coast of Miyako-jima, and there the exposure is due to a fault. We find there a bluish shale conformably overlaid by a loose brownish sandstone with a dip SW 15° or W 7° and a strike N 20° W or N-S. I found the rocks to be very rich in fossils, among which *Pecten placunoides* Martin† and *Ranella elegans* Beck* are predominant. Both are in the Miocene of Java, and the former is also abundant in the Tertiary of Formosa. *Xenophora aff. dunkeri* Martin and *Conus aff. jenkinsi* Martin are also common. Besides these, *Natica*, *Oliva*, *Turritella*, *Macha*, *Corbula*, *Lutraria*, *Tapes*, *Dosinia*, *Cardium*, *Arca*, *Anomia* and *Ostrea* are not rare. Whale bones and crab-claws are also found. A thin black-coloured coal-seam in the strata appears not so late as the fossil wood in the Tertiary of Okinawa-jima. Another thin layer of coal-seam is found in Ōgami-jima.

The Yaeyama Subgroup.

This subgroup comprises, besides the two large islands of Ishigaki and Iriomote, ten smaller islands, viz., Yonaguni, Hatoma, Nakanogan, Taketomi, Kayama, Kobama, Kami-Kuro, Shimo-Kuro, Aragusuku and Hateruma. The last four are entirely built of raised coral reefs. Nakanogan-jima, Hatoma-jima and Yonaguni-jima are composed of Tertiary sediments and raised reefs. Taketomi-jima and Kayama-jima consist of Palæozoic rocks in addition to raised reefs. In the three islands, Ishigaki-jima, Iriomote-jima and Kobama-jima, there are Palæozoic and Tertiary sediments, igneous rocks and raised reefs.

Ishigaki-jima, showing the most complicated geological structure of any of the islands of the Riukiu Curve, has been visited by Messrs. Kada and Kuroiwa and afterwards by myself. We find in this island

† Martin, Nachträge zur Tertiärschichten auf Java.—*Samm. des Geol. Reichs-Museums*, I Ser., II Band, 1881—83.

* Martin, Tertiärschichten auf Java, 1880.

the Palæozoic rocks such as clay slate, sandstone, pyroxenite or amphibolite, compact quartzite and limestone, and the igneous rocks, granite, diorite, diabase, andesite, propylite, quartz-porphyry and liparite, besides less extensive Tertiary sediments and raised reefs. The interior, with the exception of the table-land composed of reefs, is mountainous. The highest peak, Omoto-dake, rises 1680 ft. above the sea-level. The greater part of Iriomote-jima, another large island in the Yaeyama subgroup, is composed of Tertiary sediments, with Palæozoic sediments only on the north-eastern corner, and raised reefs at various places. The whole island with the exception of the very limited occurrences of raised reefs is mountainous. The highest peak, Goza-dake, has an elevation of about 1500 ft. above the sea-levle. The interior is entirely uninhabited on account of the presence of a terrible fever and poisonous snakes. People are living on the coast, and maintain communication between their villages chiefly by means of small dug-out canoes. Only a few persons have succeeded in crossing the island from its northern to its southern coast. This is a journey of only fourteen miles, but it takes at least three or four days. The three islands, Kayama-jima, Kobama-jima and Taketomi-jima, lying between Iriomote-jima and Ishigaki-jima, have Palæozoic sediments in the interior and make the connecting link between these two large islands.

Palæozoic Rocks of Ishigaki-jima. This island trending in a NE direction, shows two very narrow isthmuses of recent formation in its northern part. Also the western peninsula (B in Pl III) is connected by a plateau of raised reefs with the main body (A) of the island. Thus the island, at the time of the formation of the ancient reefs, was probably four separate islets, A, B, C and D. Clay slate, sandstone, and pyroxenite or amphibolite are found in B, C, D and in the eastern part of A. Compact quartzite, with very thin intercalations of other

Palæozoic rocks, is exposed in the central and western part of A, and shows a characteristic distribution in contrast with them. Though the Palæozoic frequently shows various distortions by the eruption of igneous rocks, yet there exists a certain regularity of inclination. The part C is made up of Palæozoic hills with a belt of reefs on the eastern and western coasts. The rocks at the northern end are chiefly pyroxene or amphibole rocks. Fūji-banare, which is a rock in the sea to the north of C, is composed also of these sediments with intervening thin layers of slate. They show a dip the same as that on the opposite coast, namely 35°—55° to SW or S and a strike from N 70°W to E—W. When we trace the Palæozoic rocks of the eastern coast of C, beginning from the northern end, we find numerous distortions of strata until we reach Yasura. The following shows the measurements of strikes and dips counted southwards from the place where a liparite dyke and a propylite sheet are found:

E—W	S70°,	N20°E	NW30°,	N50°E	NW40°,
N35°E	NW30°,	N—S	W20°,	N60°W	SW20°,
E—W	S35°,	N40°W	SW30°,	N—S	W20°,
N40°—45°W		SW30°			

The pyroxenite with some quartzose sandstone is greatly distorted, but as a whole shows a regular inclination. Rocks exposed between Yasura and Hirakubo are chiefly pyroxenite with the strike N30°—50°W and the dip SW 20°—30°. On the road from Yasura to the southern end of C, the dip is constant as is shown in the following list, no fault being observed:

N 30°W	SW 40°,	N 20°W	SW 25°,	N 30°W	SW 15°,
N 50°W	SW 20°,	N 30°W	SW 20°,	E—W	S 20°.

We meet about midway on this road a liparite stock, in contact with Palæozoic rocks, with however no trace of disturbance. Thus

their present inclination seems to be due to a pressure exerted long after the eruption of the stock. Therefore the part C, though much disturbed in its northern part, still shows the constant dip of the Palæozoic sediments, namely 20°—40° to S or SW and the strike from E—W to N20°W. This strike is apparently transverse to the longer axis of Ishigaki-jima.

The part D lying on the south of C has hills of Palæozoic sediments surrounded by a plateau of raised reefs which are now almost entirely eroded on the eastern coast. The Palæozoic consists of pyroxenite or amphibolite with small layers of clay slate and quartzose sandstone. They are very regularly inclined, with no signs of faulting or folding. The following measurements have been made on the rocks of the eastern coast beginning from the north:

E—W	S 30°,	E 30°W	SW 30°,	N 50°W	SW 60°,
N 50°W	SW40°,	N 40°W	SW 50°.	N 45°W	SW 60°,

On the mainland A, pyroxenite or amphibolite, as well as clay slate and quartzose sandstone are limited to the eastern part, while large districts of igneous rocks and compact quartzite are observed on the west. Pyroxenite is common. Quartzose sandstone, clay slate, and alternations of clay slate and quartzite are also not rare. The inclination of these rocks is quite constant. I measured, in the northwestern part, the strike N40°—50°W and the dip NE 20°—60°. Even the small coast exposure of Palæozoic sediments, lying very close to the east of the Nosoko volcano, has the strike N 30°W and the dip NE45°. Also the southern Palæozoic regions have the strike N20°—70°W and the dip NE 20°—30°; the most common measurement is N40°W, NE25°. Thus the Palæozoic rocks of A, except the compact quartzite, have dips quite opposite to those of C and D, though the strike remains the same. This is perhaps due to the great andesite eruption of the Nosoko volcano.

In the part B, pyroxenite with some alternations of clay slate and quartzose sandstone compose the Palæozoic area. Tracing the strata of the southern coast from east to west, I made the following measurements :

N20°W	SW30°,	N40°W	SW35°,	N—S	W30°,
N20°W	SW25°,	N35°W	SW20°,	N—S	W10°.

Thus the inclination of rocks is quite similar to those in C and D, and in contrast to A. On the north-west of Kabira, a little Palæozoic exposure pierced by andesite, is also inclined towards the west.

Compact quartzite is found on the mainland A and extends from the southern foot of Omoto-dake to the neighborhood of Nagura and Shikamura. The same rock is also exposed along the sea coast from Nagura to Sakieda. Near Sakieda there is only an alternation of sandstone and compact quartzite ; and finally we find only sandstone at the northern end of the quartzite region. The strike of rocks in the former region is almost always E-W, but sometimes nearly N60°E to N70°W. The dip, which is generally constant, is very steep; the strata being sometimes vertical, and sometimes inclined to N or S with an angle of 60° or 70°, but never less than 40°. In the eastern part of this region, a thin layer of clay slate is found in compact quartzite, and has the strike E-W and the dip S70°. The Bannā hill, which lies on the north of Shikamura, is composed of an alternation of clay slate and compact quartzite with the strike N50°W and the dip NE 35°. Rocks on the coast between Nagura and Sakieda are in direct contact with granite which has disturbed their layers. The following dips and strikes have been measured northwards from Nagura :

N 40°W	NE 60°	Compact quartzite.
N 60°W	NE 60°	,,
N 50°W	NE 20°	,,
N 80°W	NE 50°	,,

E—W	N 30°	Slate and sandstone.
N—S	N 10°-30°	Compact quartzite.
N 70°E	NW 40°	,,
Granite.		
E—W	vertical	Compact quartzite.
N 70°E	NW 50°	,,
E—W	N 50°	,,
N 70°E	NW 60°	Alternations of compact quartzite and sandstone.
N 30°E	NW 55°	andstone.

Palæozoic limestone found at Ishizoko and its environs has the strike E-W, and is crystalline being identical with that of the Ōshima and Okinawa groups.

There are three small islands (Taketomi, Kobama and Kayama) making a connecting link between Ishigaki-jima and Iriomote-jima. The eastern island *Taketomi-jima* is a flat table-land; its northern half is compact quartzite with sandstone and clay slate, while the southern half is entirely built of raised reefs. The Palæozoic rocks have the strike E-W, N70°E or N80°E, and the dip N30°—65°, NW35°—40°, just as on the opposite coast of Ishigaki-jima.

The principal part of *Kobama-jima*, lying on the north-west of Taketomi-jima, is composed of Palæozoic pyroxenite, sandstone and clay slate with the same strike as in Taketomi-jima, but with the dip S or SW 20°—40°.

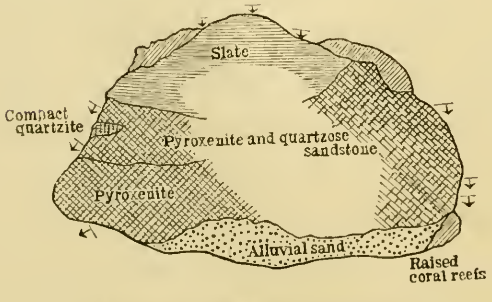


Fig. 6.—Goelogical Map of Kayama-jima.

The smallest island, *Kayama-jima*, whose tectonic condition is shown in Fig. 6, is chiefly composed of pyroxenite with a very limited occurrence of compact quartzite. These are inclined to SW only on the western

corner; in other parts we find a strike E-W, and a dip toward the south.

The Palæozoic rocks of *Iriomote-jima* are mostly pyroxenite-like and are exposed on the south of Takana, and show various distortions caused by andesite stocks.

Tertiary Rocks of Ishigaki-jima. Among these rocks which occupy very large areas in the Yaeyama subgroup, we find the following in Ishigaki-jima; namely fine-and coarse-grained brownish sandstones, compact quartzose sandstone, limestone and agglomerate tuff, all exposed in the form of patches rather near the coast. The strata are elevated hardly more than a hundred feet, except in the case of the tufaceous rocks. The most northern exposure extends from the north-western corner of Ibaruma to the cape called Ishizaki (Fig. 7). A continuation

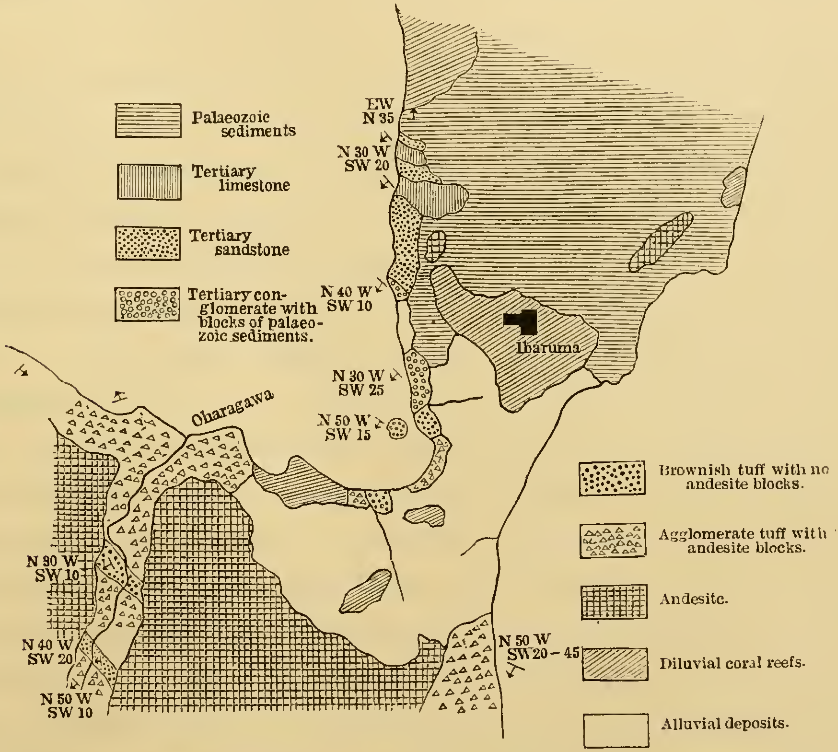


Fig 7.—Geological Map of the Ibaruma Region.

of this Tertiary is found under the andesite in the valleys of the Ohara-gawa and other rivers. The order of succession of the Tertiary rocks in this part, counting from above downwards, is as follows :

Agglomerate-tuff of andesite, with thin layers of a non-tufaceous sandstone, shale and a tuff without andesite blocks.

Brownish tuff containing no blocks of andesite.

Conglomerate with pebbles of Palæozoic sediments.

Non-tufaceous sandstone.

Limestone.

Non-tufaceous sandstone.

Limestone.

Non-tufaceous sandstone.

The lowest sandstone bed discordantly overlies the Palæozoic rocks which show a northerly dip with an angle of 35°. The agglomerate-tuff encloses large blocks of andesite which are from the Nosoko volcano, and are deposited on its fringes ; and covers quite concordantly the limestone with alternating sandstone. The latter is the same as that in Iriomote-jima, and the agglomerate-tuff contains thin layers of this sandstone, besides shale and a very hard quartzose sandstone. Thus the above mentioned alternation of limestone and sandstone is probably similar in age to the agglomerate-tuff, which has been erupted from the Nosoko volcano. This tuff is not only found along the northern side of the volcano, but also composes the isolated hills near Tamatori-zaki, besides being exposed in small patches in the neighborhood of Inoda. In this rock there are intercalated, in some places, thin layers of bluish sandstone which show the strike N50° or E-W, and the dip SW 20°–45° or S 30°–45°. Small exposures of the limestone, together with Palæozoic rocks, are found on the coast near Inoda. A little to the south of these exposures, there is a small region of Tertiary sediments with andesite in contact, which forms a hill. These sediments are

separated from the limestone by Alluvial sand and raised reefs. The entire region of the cape Nobara-zaki is of Tertiary rocks showing the following order of superposition :—

Bluish sandstone.
Tuff without andesite blocks.
Agglomerate-tuff with andesite blocks.
Brownish tufaceous sandstone.

All the rocks lying on the northern and eastern sides of this andesite hill show the dip varying from S W 25° to S 30°, with the strike from N 60° W to E–W. Even at the line of contact with the andesite, there is no marked disturbance of bedding. On the south, limestone exposures along the coast are separated from these exposures by a narrow stripe of Alluvial sand. The limestone shows a regular southward dip with an angle of 20°, and consists almost entirely of the calcareous algæ, identical with *Lithothamnium rosenbergii* Martin* from the miocene of Timor. Besides these only one large Irregular Echinoid belonging to the *Spatanginae* has been collected. The limestone extends more than a thousand feet along the shore, and is covered at its southern extremity by sandstone containing pebbles of Palæozoic sediments. In the neighborhood of Karadake on the west of Tōzato and Moriyama, there is a small exposure of sandstone with pebbles of Palæozoic sediments. It shows a dip 31° south as in the other parts of Ishigaki-jima. Thick beds of limestone, with the same appearance and fossil contents as those above mentioned, are on the north of Miyara-mura. I found here two thin intervening layers of the pebbly sandstone, which, as in other places in the island, show the dip 25°–30° SW and the strike N 50° W. Sometimes the Tertiary rocks are in direct contact with andesite,

* Martin, Die versteinerungsführenden Sedimente Timor's. *Samm. des Geol. Reichs—Museums in Leiden*, I Serie, I Band, 1881.

probably a dyke through the Palæozoic, but are not disturbed. Sometimes the Tertiary sandstone is deposited over the andesite. The sandstone in two small regions, namely near Ōhama-mura, and on the north-east of Shikamura, is that exposed after the erosion of the overlying reefs; and shows a regular dip towards the south. That exposed near Ōhama-mura contains imperfect casts of fossil leaves. Another exposure of limestone in B has the same character and same inclination (N50° W, S W 40°) as those in the other parts. In the western portion of B, there are also exposures of agglomerate-tuff with intercalations of sandstone and shale, showing the strike varying from N 40° W to N–S, and the dip nearly westward with an angle 10°–25°. The bedding of the rocks has not been modified by the andesite, with which they are in direct contact in some places.

The characteristics of the Tertiary of Ishigaki-jima consist of the deposition of agglomerate-tuff near andesite masses, and of limestone at some distance from the andesite; the andesite showing no influence upon the bedding of the other two rocks. Except on the western side of the Yarabu peninsula, the various Tertiary sediments are all regularly inclined southwards with the strike varying from N 50° W to E–W. This direction of inclination is moreover general in the Palæozoic sediments. There may perhaps have taken place a single great folding, after the deposition of the Tertiary rocks and the contemporaneous eruption of andesite. The single limestone bed on the fringe of the island now appears in small separate tracks always with the same inclination.

The Tertiary of Kobama-jima, which is found only in its south-eastern part, consists chiefly of fine-grained brownish sandstone with thin layers of conglomerate containing pebbles of Palæozoic rocks; besides these there is a very small exposure of *Lithothamnium*-limestone, like that found in Ishigaki-jima. I found also a thin coal-bed at the

south-eastern corner. Inclination is variable, but generally towards the east or south. Beginning from the northern end of the Tertiary region I have found the following beddings:—N-S, E10°-20°; then N20°-50° E, SE 10°-25°; and lastly E-W, S 5°. An exceptional dip towards the north-east is sometimes found in small exposure, but there are no westward ones.

The Tertiary of Iriomote-jima. This island, which is principally composed of Tertiary rocks, has the Palæozoic only on the north-eastern corner, besides scattered exposures of the ancient fringing reefs. The Tertiary rocks are rather regularly inclined and are never horizontal; they are mostly fine-grained, bluish or brownish sandstones, the latter of which often shows a false bedding. Shale is sometimes intercalated in these rocks. Coarse-grained brownish sandstone and conglomerate are less developed. Several coal-seams are found in the western part, each dipping towards the west, and with a strike nearly N N E.

The uppermost bed of the Tertiary, which is exposed near the western coast, is a calcareous sandstone with fossil shells. The exposures are found on the western corner of Hoka- (Soto-) banare and the point projecting between Urauchi-zaki and Unari-zaki. The fine-grained brownish sandstone is found between the calcareous sandstone and the first or uppermost coal-seam, and has the strike N 30°-50° E and the dip N W 8°-10°, as measured in Uchi-banare. This first coal-seam, which is only 10 inches thick, is exposed on a curved line running from the south-eastern corner of Hoka-banare toward Uchi-banare. The second seam is the greatest having a thickness of 3—4.5 ft. in Uchi-banare, and of 1 ft. on the north of Hoshidate and on the south of Unari-zaki. Between the first and second seams there is fine-grained brownish sandstone with a little shale. In Uchi-banare, the Tertiary rocks show the strike N 45°-60° E

and the dip N W 10°–20°; a slight change of bedding is observed on the north of Hoshidate, where we find them N 30°–60° E and and N W 5°–10° respectively on the north-western edge of the island. A small strike-fault in Uchi-banare has raised the western part of the island about forty or fifty feet. The third seam about 1 ft. in thickness is exposed on the main island at a place opposite Uchi-banare, then on the south-east of Sonai, on the north of Hoshidate, on both banks of the Urauchi-gawa and finally on the west of Uebaru. At the first mentioned place the seam has been upheaved by a fault lying in the sea between Uchi-banare and the main island. Between the second and third seams there is chiefly brownish sandstone, which contains, near Sonai and on the west of Uebaru, bands of shale. The sandstone shows the strike N 30° E and the dip N W 5°–10° near Sonai. The measurement is however N 40° E and N W 10° in the neighborhood of Aka-saki on the south, and from N 40° E to N–S and N W 10° to W 5° near Hoshidate on the north. Then proceeding towards the north, I measured N 20°–60° E. N W 5°–10° on the north bank of the Urauchi-gawa and N 30°–60° E, N W 10° on the west of Uebaru. The fourth seam, about 6 inches in thickness, is exposed on the upper course of the Nakara-gawa, on the east of Sonai and on the south of Uebaru. Above this seam there is also found chiefly brownish sandstone with the usual westward dip. The most prevalent bedding is N 40° E, N W 30° in the upper part of the Nakara-gawa; from N–S to N 20° E, and from W5° to N W 10°, on both banks of the Urauchi-gawa. I have found, on the east of Sonai, a thin limestone layer full of *Orbitoides*, together with a few remains of *Lithothamnium* and *Amphistegina*. The fifth seam is found on the steep mountain-side far to the south-east of Uebaru. The strata above this seam, chiefly of sandstone, shows N 30° E and N W 10° on the upper course of the

Nakara-gawa; N–S, W 5°–20°, on the upper part of the Urauchi-gawa; and N 30°–40° E, N W 15° on the east of Uebaru. At a considerable distance from this seam, two other coal-seams, namely the sixth and seventh are said to exist near the summit of Goza-dake, the highest peak in this island. On the northern part of the island, the beds underlying the fifth seam show the same inclination as above stated, and consist of sandstone with thin layers of shale and conglomerate. Their general strikes and dips, observed on the route from the east of Uebaru to Takana are as follows. Until we reach Intaya we find sandstone showing the strike N 30°–50° E and the dip N W 5°–15°, then conglomerate from Intaya to Aka-banare, and sandstone with shale thence to Takana, the last mentioned rocks showing the strike N 40°–60° E and the dip N W 10°–15°, except in the case of some small folds.

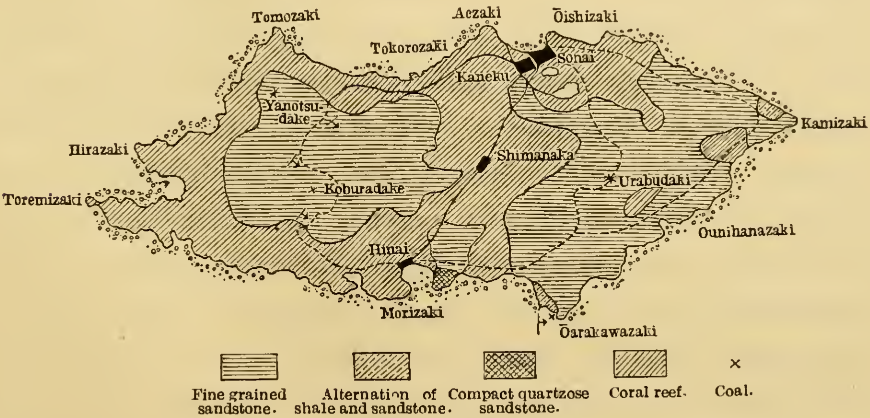
Then coming to the east coast, we find on the north of Komi quite different rocks with other inclinations. These are agglomerate-tuff with andesite blocks, and conglomerate with pebbles of Palæozoic rocks. They are inclined to S or S W 10°–40°, with the strike E–W or N 30° W, and are probably of the same age as the agglomerate-tuff in Ishigaki-jima. Rocks found a little to the south of Komi are sandstone with a little shale as in the northern and western parts of Iriomote-jima. On the route thither as far as to a region near Kuira-gawa, the inclination of the rocks is not as regular as that already mentioned for these parts. Near Komi the bedding is variable, being sometimes N 30° E, N W 15°, sometimes N–S, W 25°, in other cases N 60° E, S E 5.° Thence and until a short distance from Nakama, the rocks are regularly inclined to S E 5°–30°, with the strike N 30°–70° E. I found at Nakama-zaki a thin coal-seam, probably the lowest in the island. The stratification is N 70° W, S W 30° or E–W, S 30° at Nakama, and N 70°–80° E, S E 20°–40°

or E–W, S 30° in the vicinity of Haemi. Then along the southern coast from Haemi to Kanokawa, the inclination is different. After going about a mile to the west of Haemi, the rock observed is a fine-grained sandstone, which shows various inclinations, until finally the dip is due north. After this point and until Kanokawa is reached, we find the strike and dip N 70°–80° E, NW 5°–25°, N 80° W, NE 20°, or E–W, N 30°. From Kanokawa to the west of Ochimizu-zaki where a thin coal-seam occurs, I found the strike to be nearly the same, viz., E–W and the dip N 20.° At Ubiraishi there is a calcareous sandstone with fossil shells, closely resembling the rock on the north of Urauchi. Then we enter the northern and western parts of a tongue shaped region including the places called Yaeme-zaki, Nohama, Sakiyama, Amitori, Funauke and Kuira-gawa. Here the Tertiary rocks are very much disturbed, the dip and strike never remaining constant even for a short distance; the coast is very deeply indented as is shown in the plate. All these are perhaps due to a fault along the south-western coast of the islets Uchi-banare and Hoka-banare. In this region, which consists essentially of brownish sandstone, I have found four thin coal-seams which can not be identified with those in the main part of the island. The first seam is exposed at Nohama ; the second runs from Sakiyama to the south of Amitori ; the third is exposed on the south of Amitori; and the last is on the road from Ubiraishi to Ochimizu-zaki. In the brownish sandstone are sometimes found shale beds ; a calareous shell-bearing sandstone, probably a continuation of that of Ubiraishi, is seen on the east of Funauke and in Saba-zaki.

Though the whole interior is almost entirely composed of Tertiary rocks, they contain very few fossils. Except *Lithothamnium* and *Orbitoides* and a few other Foraminifera found in the limestone, and some indeterminable shells in the calcareous sandstone, I have found

only the large Echinoids, *Echinodiscus* and *Astriclypeus* in the sandstone of Hoka-(Soto-)banare. The former has a diameter of 9 cm. and greatly resembles *E. placenta* Duncan and Sladen in the form of its lunules. It is interesting to note, that I found the same species in the Tertiary of northern Formosa, which contains numerous coal-seams and consists of rocks which are the same as those in Iriomoto-jima. The latter genus is now represented by one living species *A. manni* Verill. In 1899, I studied the *Astriclypeus* from the Tertiary of Mizuhomura, Prov. Kai (probably Miocene), and named them *A. integer*. The specimens from Iriomote-jima are rather ill-preserved, yet showing sufficient characters to identify them with the same species. Moreover the Tertiary near Mizuhomura incloses a thin limestone with *Orbitoides* very closely resembling that in Iriomote-jima.

The Tertiary of Yonaguni-jima. This island consisting of Tertiary rocks, is disposed in two hilly regions separated by raised reefs (Fig. 8.). The eastern half is called Urabu, and the western Kobura.



Scale 1:100000.

Fig. 8.—Geological Map of Yonaguni-jima.

Raised reefs are also observed along the margin of the hills, especially on the western and northern sides (Pl. V.). The Urabu region is elongated from N to S, but Kobura is broad in shape. Between them,

there probably existed a fault line on both sides of which we observe a difference in petrography and tectonics. The western half is composed entirely of brownish sandstone dipping to SE 10°—30° with the strike N 30° E. But in the other part, brownish sandstone is seen only on a high level, and under it are found a hard bluish sandstone, compact quartzose sandstone and shale with a thin coal-seam. Fossil plants and Echinoids are found just above the coal-seam. The bedding of these rocks is N—S, E 20°. Though the island is elongated from east to west, yet the strike of rocks is not parallel to the longer axis of the island, but is really perpendicular to it.

Igneous Rocks in the Yaeyama Subgroup. Among the plutonics, granite, of which biotite-and hornblende-granite are the chief varieties, occupies large areas in Ishigaki-jima, forming elevation of 1680 ft. It has pierced compact quartzite on the south and west, and other Palæozoic sediment on the east. Olivine-diorite is found in the granitic region on the south of Omoto-dake, their mutual relations being still unknown. Besides, in Uchino-mura in the northern part of the part D, there are small exposures of diabase and quartz-porphyry. In the part C, a liparite dyke is found in the north-east, and a liparite stock in the south-east, both of which run from NE to SW. Andesite is predominant in Ishigaki-jima. Pyroxene-andesite is the principal lava from the Nosoko volcano, and extends even to the north-west and north-east of Ibaruma. Around the volcano we find agglomerate-tuff with angular blocks of andesite. The volcano is much eroded, showing no trace of its original form. Its highest part, Nosoko-māhē, has an elevation of 951 ft., and forms a sharp point standing out prominently from the surrounding hills (the remains of the Nosoko volcano), which again descend by perpendicular cliffs to the plateau on their northern side (Fig. 9). The two independent volcanic masses in the west of Nobara-zaki as well as in the part B con-

Fig. 9.—View of Nosoko volcano seen from Nosoko-zaki on the west.

sist of pyroxene-andesite. Stocks of the same rock are found on the north of Nosoko, in the south-western part of C and the north-west of Kabira, and extend from NE to SW. I found two dykes of pyroxene-andesite on the north of Miyara and another on the south of Omoto-dake. Dykes and stocks of the same rock are also found in the south-western and north-eastern corners of Kobama-jima and in the north-eastern corner of Iriomote-jima. Propylite sheet is exposed on the coast, north of Yasura in Ishigaki-jima.

The andesites of the Yaeyama subgroup pierce through the Palæozoic sediments but not through the Tertiary. Though some places in Ishigaki-jima show the Tertiary rocks in contact with the andesite, yet there is no contact change nor tectonic disturbance in the former. The agglomerate-tuff of andesite alternates with thin non-tufaceous sediments. This shows that the deposition of the Tertiary rocks of Ishigaki-jima took place either contemporary with, or else immediately before or after the andesite eruption. The regular bedding of the Tertiary, as well as that of the Palæozoic sediments of Ishigaki-jima is characteristic, showing a single folding pressure after the eruption of the volcanic rocks. In contrast with the Tertiary of Ishi-gaki-jima, that of Iriomote-jima has a very great thickness, contains several coal-seams, and is generally inclined to NW in the western, but not in the eastern part. Although this Tertiary is doubtless a

continuation of that of Formosa, as is explained hereafter, the strike of the western part thus differs from that of the latter region which is E—W. This is probably due to a fault running N—S, which direction is also taken by a line of andesite eruption in Ishigaki-jima. The strike of rocks in Yonaguni-jima again shows the existence of a fault of the same direction running through its central portion. Previous observers have assumed a great fault line parallel to it on the eastern side of Formosa. These lines of weakness all running N—S were probably caused by a pressure independent of that which folded the Riukiu Curve, and it is also probable that the former pressure preceded the latter. The "Mayon system" of Prof. Kotô* will perhaps show some relation to these lines.

VI. UNINHABITED ISLANDS IN RIUKIU.

Under this heading will be treated the Borodino and Pinnacle groups, both lying at a considerable distance from the other islands in the Riukiu Curve.

The very small islets scattered at a distance of about 155 miles to the south-east of the southern point of Okinawa-jima, and forming the *Borodino Group*, are named Rasa, South Borodino (Minami-ōagari) and North Borodino (Kita-ōagari). The first is in lat. 24° 32′ 30″ N and long. 131° 19′ E, the second in lat. 25° 55′ N and long. 131° 14′ 42″ E, and the third lies about 6¾ miles to the north-east of the second. Their length and width measure respectively 2.5 and 1 miles, 5 and 3 miles, and 3 and 2 miles. They are all composed of raised reefs which end in perpendicular cliffs on the shore.

Other small islets to the north-east of the Yaeyama subgroup,

* Kotô, On the Geologic Structure of the Malayan Archipelago—*Journ. Coll. Sci. Imp. Univ., Tōkyō*, Vol. XI, Part. II, 1899.

form the *Pinnacle Group* and are named Hoa-pin-su (Waheizan), Chia-u-su (Kōbitō or Kuba-shima), the Pinnacles and Raleigh (Sekibitō or Kume-aka-jima). These islands have been visited by Messrs. Miyajima, Kuroiwa and others.† Hoa-pin-su, the largest island in the group, is in lat. 25° 47′ 7″ N and long. 123° 30′ 30″ E, at a distance of 90 miles from the western edge of Miyako-jima, 88 miles from Hoka-banare in Iriomoto-jima, and 100 miles from the north-eastern coast of Formosa. It is elongated from east to west, and is 4 miles long and 3 miles broad. The highest peak in the island has an elevation of 1180 ft. above the sea-level. The oldest rock is diorite, found on the southern coast. The greater part of the land is occupied by Tertiary sandstone, which is inclined to the north at an angle of 10°—20°, and becomes more coarse-grained toward its upper part, finally passing into a conglomerate. A thin coal-seam about 3 inches thick is found in the lower part. Raised reefs are found on the southern, western and eastern corners of the island. The Dinnacles lie a few miles to the north-east of Hoa-pin-su, and consist of several rocks such as Kita-and Minami-kojima and others, which are chiefly Tertiary sandstone. The sandstone is inclined to the north at 40° on the west of Minami-kojima. Raised reefs are also found on these two rocks, especially on the northern side of Minami-kojima. Chia-u-su lies 15 miles north-east of Hoa-pin-su (lat. 25° 58′ 30″ N and long. 123° 40′ E), and is about 2 miles long and a mile wide. The highest point measures 600 ft. above the sea-level. According to the petrographical examination by Prof. Kotô, the whole interior is a mass of basalt. The Raleigh rock, situated in lat. 25° 55′ N and long. 124° 34′ E, lies about 50 miles to the east of the above-mentioned islands,

† The China Sea Directory. Vol. III., 1894.

† Miya-jima, 黄尾嶋 (Kōbitō)—*The Journal of Geography, Tōkyō*, Vol. XII., No. 144., 1900.

† Kuroiwa, 尖閣列島探險記事 (Note on the Pinnacle Islands)—*The Journal of Geography, Tōkyō*, Vol. XII., No. 141, 1900.

and is $1\frac{1}{2}$ miles long and a mile wide. The highest point rises 270 ft. above the sea-level. Mr. Kuroiwa has found the island to be of an agglomerate-tuff of andesite.

VII. UNINHABITED ISLANDS LYING TO THE NORTH OF FORMOSA.

There are three islands scattered at a distance from 20 to 30 miles north-east of Kelung (Kiirun) in Formosa. The most southern is called Agincourt (Hōkwatō) (lat. 25°38′N, long. 122°5′$\frac{1}{2}$ E), and has, according to "the China Sea Directory," a round summit, 540 ft. high, stretching out into high bold headlands on the north and south. All the eastern side is very steep, the western is less so. Pieces of rocks composing the island have been collected and sent to me by Mr. Ōsumi. By the determination of Prof. Kotô, they are found to be hypersthene-basalt and hypersthene-andesite. The Crag (Menkwatō) (lat. 25° 29′ N and long. 122°7′E) lies 9 miles SSE from Agincourt; and is, according to Mr. Saitō,* elongated N-S, with a length of 1640 ft. and a width of 984 ft. The coast generally has steep cliffs. The highest point is in the eastern part of the island and reaches the height of 180 ft. above the sea-level. The whole island is entirely composed of neovolcanic rocks. The volcanic centre is now invisible, but it was probably situated on the east of the highest peak. Basaltic andesite was first erupted, and then a small amount of volcanic ash and breccia deposited upon its sheet. Dykes of the same composition were finally erupted through these rocks. The southernmost island, the Pinnacle (Kwaheitō), lies NE by N of the entrance of Kelung harbour and at a distance of 19 miles from it, that is in lat. 25°26′N and long. 121° 57′E. It is a rugged mass of rock, 170 ft. high, with perpendicular

* 基隆沖無人島踏査報文 (Report on a Trip to the uninhabited Islands lying off the Coast of Kiirun, 1900., *in Japanese*).

sides. The outline is rectangular and the island is elevated 984 ft. above the sea-level. According to Mr. Saitō the rock of this island is also entirely basaltic andesite.

PART IV.—Geology of North Formosa and its Relation to the Riukiu Islands.

North Formosa consists of Tertiary sediments, pierced by andesite at the northern end. The Tertiary strata, which are never horizontal, are, on the whole, comparatively regularly folded. According to Mr. R. Yamashita eight parallel series of coal-seams are exposed in this district.

1st., (the uppermost), The Kusshaku series, with one seam, running through Ōkutsu, north of Kusshaku, Chōsōkei and Gyokō.

2nd., The Shinten series, with two seams, running through the west of Ōkutsu, Shintengai, Sekiteigai and Chōsōkei.

3rd., The Keibi series, with two seams, running through Ōkeikō, Shōsokō, east of Keibigai, Shinkogai, Fūshirin, Sekikan, Sōkei, and Banshikō, and south of Zuihō.

4th., The Shinkyakutei series, with two seams, running through Basozan, Chōhō, Reisuikō, Gyūhō, Nanseikaku, Jūgofun, Rokuchōri, Sanchōri, Nankōzan, Hakuhōshiko, Goto, Shikyakutei, and Shin-ō-kō and south of Hatto.

5th., The Denryōkō series, with four seams, running through Naikokōko, Parenkōkō, Hokukōkō, Yūrakōkō, Kōshinai, Sekikōkō (near Kelung), Denryōkō and Hatto.

6th., The Gwaibokuzan series, with two seams, running through Naikosankyaku (north-west of Shakkō), Jūshifun, Rokuryō, Daiburon, Daikanrin, Naibokuzan and Gwaibokuzan.

7th., The Kankyaku series, with two seams, running through Kentan (near Taihoku), Hasshirin (Pachinā), Kankyaku and Basokukōkei.

8th., The Intanshinai series with two seams, running through Kirigan, Sankakuhō, Intanshi (south of Kinpōri) and Hattoshi.

Mr. Yamashita has found two anticlinal and three synclinal foldings in the eastern part, and one anticlinal and two synclinals in the western part. All their axes run E-W, but most of them can not be traced from one end to the other of the district observed; the sole exception being a synclinal which runs through the south of Chōsōkei, the north of Heirinbi and the south of Shintengai. The Tertiary rocks, on the north of this axis, which show the above mentioned small folds, are *mostly* inclined to the south, while those in the southern half are *almost always* inclined to the north. Besides there are, in the north, all of the seams; but in the south, there was found only the uppermost seam near the synclinal axis. Though the greater part of the region in the south is now difficult to traverse on account of the wildness of the aborigines, yet it is probable that there are very scanty coal-deposits in that region. In the north, many limestone layers and several fossils are found. In the south, it is not yet reported that limestone exists, and fossils are moreover very rare. Rocks found in the north are mostly shale or fine-grained brownish sandstone, both being shallow-sea deposits. In the south, the uppermost strata are brownish shale, in which nodules are more abundant towards the lower part, which is irregularly split up into angular fragments. This part, which is slate-like, finally passes into clay slate which is in all exposures conformable with the shale. The annexed figure (Fig. 10) shows a profile, found in the northern half of the Tertiary region.

In these rocks there can not be distinguished any particular horizon either by fossil contents or by petrographical characters. The limestones which are found in Ajukō, Shakokō, Reisuikō, Yūra and between Sanchōri and Shinkōgai, are mostly more than 10 ft. in thickness, but at Yūra they are only a few feet thick. *Lithothamnium rosenbergii* Martin predominates as in the limestone of Ishigaki-jima. I found in the Tertiary rocks in several places in this northern portion the following fossils, which were partly determined by B. Newton and R. Holland* and partly by myself:

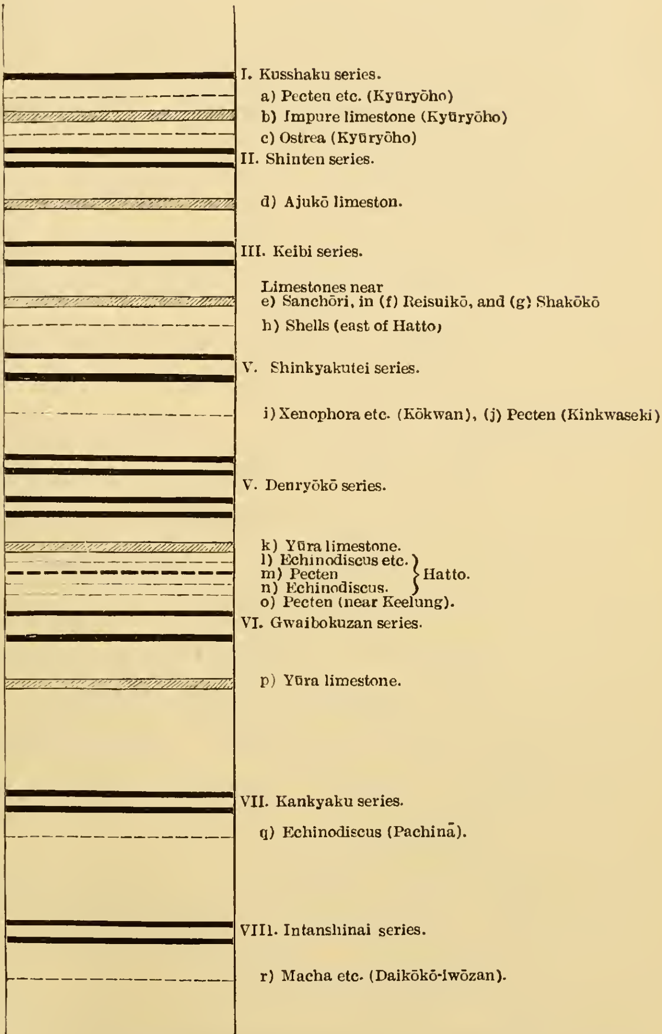


Fig. 10.—Profile of the Tertiary rocks on the northern side of their principal synclinal axis, with various limestone and coal beds and fossil horizons.

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* Newton and Holland, Notes on microscopic Sections of Limestones from Formosa.—*The Journ. Geol. Soc. Tōkyō*, Vol VII., No. 81, 1900.

I collected peculiar large cone-shaped fossils from Sekiteigai and Shakōkō. Prof. Kotô sent them to Dr. R.B. Newton for determination, and has been recently informed that they belong to Cellepora in Bryozoa.

a) Kyūryōho (sandstone): *Pecten placunoides* Martin, *Ostrea sp.*, *Arca α sp.*, *Arca β sp.*, *Venus sp.*

b) Kyūryōho (impure limestone): indeterminable shells.

c) Kyūryōho (sandstone): *Ostrea sp.*

d) Ajukō (limestone): indeterminable shells.

e) Between Sanchōri and Shinkōgai (limestone): *Lithothamnium rosenbergii* Martin, *Globigerina bulloides*, *Bigenerina sp.*, *Textilaria sp.*, *Orbitoides verbeeki* New. and Hol., *Heterostegina sp ?*, *Valvulina sp ?*

f) Reisuikō (limestone): *Lithothamnium rosenbergii* Martin, *Gypsina inhoerens* Schultze (?), *Linderina sp* (?)., *Miliolina sp.*, *Pecten placunoides* Martin, *Ostrea sp.*, Coral, Echinoid.

g) Shakōkō (limestone): *Lithothamnium rosenbergii* Martin, *Gypsina inhoerens* Schultze (?), *Gypsina sp.*, *Linderina sp.*, *Textilaria sp.*, *Micheliniana sp.*, Sponge, Coral, Echinoid, *Pecten placunoides* Martin, *Ostrea sp.*

h) East of Hatto (sandstone): indeterminable shells.

i) Kōkwan (shale): *Xenophora sp.*, *Ranella elegans* Martin, *Yoldia sp.*

j) Kinkwaseki (sandstone): *Pecten placunoides* Martin.

k) Yūra (limestone): *Lithothamnium rosenbergii* Martin, *Linderina sp.*, Echinoid.

l) Hatto (sandstone and shale): *Echinodicus formosus* Yosh., *Astriclypeus integer* Yosh., *Dolium sp.*, *Voluta sp.*, *Cerithium sp.*, *Natica sp.*, *Dosinia sp.*, *Venus sp.*, *Pecten placunoides* Martin, *Arca sp.*

m) Hatto (calcareous sandstone): *Pecten placunoides* Martin.

n) Near Hatto (sandstone): *Echinodiscus formosus* Yosh.

o) Near Kelung (sandstone): *Pecten placunoides* Martin.

p) Yūra (limestone): *Pecten placunoides* Martin.

q) Pachinā (sandstone): *Echinodiscus formosus* Yosh.

r) Daikōkō-iwōzan (sandstone): *Macha sp.*, *Arca sp.*, Coral. In the southern half of the island I have found a tectonic different from that in the northern half. In the eastern part of the former we find a shale with a little sandstone as at the southern foot of Sōrei. Then toward Taikeishō, the rock is found to be chiefly bluish shale with nodules. Thence to Kōfunshō, it shows a fracture with spindle-shaped fragments. Bluish shale, with a few layers of quartzose sandstone and hard sandstone, is then exposed on the south of Kōfunshō. In this shale, whose exposures on the north of Giran have been described by Mr. Ishii as "Mesozoic slate," I have collected *Tellina* and *Schizaster* at Fukutokkō. The latter is a form found in all rocks from Tertiary to Recent. Thus the boundary between the Tertiary and older rocks must be found to the south of Giran.

The geology of North Formosa shows a connection with that of the Saki-shima group. (1) Many coal-seams of the same character are common to both. Though they are less in number and thickness in Iriomote-jima (Saki-shima group), yet they are all found in the same fine-grained brownish sandstone in Formosa as well as in Saki-shima. Yonaguni-jima lying between Formosa and Iriomote-jima, as well as Miyako-jima, have traces of the same coal-seams. (2) Though fossils are rather scanty in both regions, I found in Formosa and Iriomote-jima, the characteristic *Echinodicus* and *Astriclypeus* in a rock lying between the coal-seams. The Echinoid found close to the coal-seams in Yonaguni-jima is probably of the same species. (3) The typical species of *Pecten* occurring with *Echinodiscus* in Formosa, is also abundantly found in Miyako-jima. (4) The Tertiary of Formosa has the strike E-W, thus the strata running towards the Saki-shima group, whose western part is opposite to Formosa, are entirely Tertiary.

The *Echinodiscus* is a form found from Miocene to Recent, and

my specimens of it closely resemble *E. placenta* Duncan and Sladen* from the Miocene of India. But the latter species has broader lunules running in a line through the apical system to the tip of the petals; the petals are open and have less numerous ambulacral pores; and the tip of the petal is very distant from the lunule. Our species of *Echinodiscus*, as well as of *Astriclypeus* were erroneously described by Prof. Lebour as *E. biocululatus* Ag. and *E. bisperforatus* Leske.† The largest specimen of *Echinodiscus* in my collection has a diameter of 140mm. I propose for it the new specific name *E. formosus* with the following diagnose.

Test thin, flat, very slightly raised dorsally; broadly ovoid; widest posteriorly, not so strongly truncated as *E. biocululatus* Ag. Apical system nearly central, madreporite central, polygonal; four genital pores exsisting in the basal plates. Petals nearly closed; anterior longest. The length, breadth, and number of the pores in each petal in a specimen of about 100 mm. diameter are as follows:

	Length of petal. mm.	Width of petal. mm.	Number of pores.	Width of poriferous zone. mm.
Odd ambulacrum.	25.	11.5	75	4
Anterior paired ambulacra.	22.5	11.5	67	4
Posterior paired ambulacra.	22.5	11.5	67	4

Lunules two, one in each posterior ambulacral space; large and elliptical; 13.5 mm. in length and 9 mm. in width in the same specimen; these becoming more elongated in the older specimens: larger axis of lunule making about 30° with the median line of the ambulacrum. Distance from the tip of petal to the lunule only 5 mm. Peristome central, very small; groove single near peristome, and soon bifurcating.

* M. Duncan and W.P. Sladen, The fossil Echinoidea from the Gáj or miocene Series —*Mem. Geol. Survey. India*, Ser. XIV., Vol. I. 3., Fas. V. 1885.

† G.A. Labour, Note on some Fossils from North Formosa. &c.—*Trans. North Eng. Inst. of Mining and Mechanical Engineers.* Vol. XXXIV., Part. I., 1885.

Astriclypeus integer Yosh., found with *Echinodiscus* in Formosa and Iriomote-jima has been also found from the Miocene Tertiary near Mizuho-mura, Prov. Kai in Honshū. Near this place, there is found a limestone filled with *Orbitoides*. Nearly similar *Orbitoides* were collected by me in greater numbers from the limestone in Iriomote-jima. R. B. Newton and R. Holland have mentioned† that the *Lithothamnium* in the Tertiary of Formosa belongs to the same species as those in the Miocene of Timor. Thus the Tertiary sediments of the Saki-shima group and of the northern part of Formosa are of the same horizon belonging to the Miocene.

According to earlier investigations by many geologists, the main part of Formosa, consisting of slate, granite, Palæozoic limestone and Archean (?) rocks, is surrounded by Tertiary sediments mainly developed on the north, east and west coasts. The limestone and granite are no doubt the same as those in the Riukiu Curve. I found also many blocks of pyroxenite-like rocks from the neighborhood of Giran in Formosa. The greater part of Formosa is of clay slate, whose age is still unknown, but may be regarded as Mesozoic and Palæozoic. No indisputably Mesozoic rocks have yet been discovered in the island.

PART V.—Conclusion.

The Riukiu Curve consists of a number of islands, forming a long arc between Kyūshū and Formosa. The difference in longitude of the two extremities of this arc is about twice that measured in Kyūshū, while the difference of latitude is thrice that in Kyūshū. The sedimentary rocks in the Curve are never horizontal, showing usually a

† Newton and Holland, Note on microscopic Sections of Limestones from Formosa, &c.—*Jour. Geol. Soc. Tōkyō.*, Vol. VII., No. 81, 1900.

regular inclination, and are limited to definite zones. The raised reefs, which are found in various districts, are however quite horizontal. Only the Tertiary rocks in the northern half are rather irregularly inclined, sometimes being horizontal. The principal rocks of the Curve are the Palæozoic, in which limestone and compact quartzite show the occurrence different from slate, sandstone, and pyroxenite or amphibolite. The latter series of rocks are found in a zone running through Ōshima, Tokuno-shima, Okinoerabu-jima Yoron-jima, Okinawa-jima, the Kerama subgroup, Ishigaki-jima and Iriomote-jima. The former are found on the western side, namely in the western part of Ōshima, the Iheya subgroup, the tongue-shaped western region of Okinawa-jima, in its dependent isles, Ie, Sesoko, Yagaji and Kouri, besides in Ishigaki-jima and Taketomi-jima. Both series are all regularly inclined. Thus in Ōshima and Okinawa-jima, they have the strike parallel to the length of the island and the dip toward the west. In Tokuno-shima, Okinoerabu-jima and others, we find either the same strike of rocks or the longer axis of the island parallel to the Riukiu Curve. The islands of the Iheya subgroup are arranged parallel to the Curve. Though the rocks in the Yaeyama subgroup have been partly disturbed by volcanic eruptions, yet they show on the whole regular dips. A continuation of the above mentioned Palæozoic rocks is also found in Formosa, in the interior of which slate prevails and other rocks are of limited occurrence. The above-mentioned systems of rocks belong to the so-called *median row* of islands in the Riukiu Curve.

Erupted through these rocks, there are various Pre-tertiary igneous rocks, the chief of which are granite and diorite, found in Yaku-shima, Ōshima, Tokuno-shima, Ishigaki-jima and Hoa-pin-su. Similar granite is found near Girau in Formosa, and in the south-eastern part of Kyūshū.

The formation of the Curve has been explained by Prof. Kotô, as due to the depressions of the Tung-hai ("East Sea" of China), which took place mostly in the Tertiary period. Thus the greater part of the Palæozoic rocks in the above mentioned islands is inclined to the west. Sometimes the strike of the beds, and sometimes the longer axes of islands, are parallel to the direction of the Curve. The fissure of volcanic eruptions, which is continued to the series of Kyūshū volcanoes, such as Kiri-shima, Sakura-jima and Kaimon, is found on the *inner side* of the sedimentary zones of the Riukiu Curve, and is traceable through the islands, Take-shima, Iwō-jima, Kuro-shima, Kuchinoerabu-jima and the Tokara group, and further to Tori-shima on the west of Tokuno-shima, Aguni-jima and Kume-jima in Okinawa (Pl. II). The probable south-western prolongation of this great fissure is through the uninhabited islands on the north-east of Formosa, through Daiton-zan in the same island and the Hōko group (Pescadores). The volcanic rocks in Ishigaki-jima have an aspect different from those in this line of eruption and may perhaps be continuous with those in the southern Pacific Ocean. There must be some fissures, running from south to north, in the sea between Formosa and the Saki-shima group. They were probably caused by a pressure independent of that which folded the Riukiu Curve; and the volcanic rocks in the Yaeyama subgroup and those of the other islands in the Curve may belong to different periods, the former being older. The thick beds of Iriomote-jima were probably raised by a volcanic eruption in the Yaeyama subgroup. Limestone and sandstone, of the same age as this eruption, have been deposited in Ishigaki-jima, alternating with agglomerate-tuff. In Ishigaki-jima, the Tertiary as well as the Palæozoic rocks have not been disturbed by volcanic action, and remain equally inclined in the same direction with the strike nearly E–W, the direction of which does not coincide to the longer

axis of the island. The arrangement of islands in the subgroup and their stratification of rocks are probably due to the last folding of the Riukiu Curve.

The *outer* sedimentary zone of the Riukiu Curve is made up of Tertiary sediments, and extends through Tanega-shima, Kikaiga-shima, the islands lying on the east of Okinawa, and the southern part of Okinawa-jima. Some islands are elongated from north to south, and Tanega-shima, Kikaiga-shima and others have the strike of rocks coinciding with the direction of the Curve. Comparing the character and stratification of the Tertiary of the above regions on the one hand, with those of Formosa and the Yaeyama subgroup on the other, I have found the following differences. (1) The rocks are, in the former, loose sandy shale, without any hard rocks or limestones such as are found in the latter. (2) There are, in the former, very small fossils, mostly of existing forms, in contrast with those in the latter. (3) There are brown-coal seams in the latter, while in the former we find lately appearing remains of wood in Okinawa-jima and a few other islands. (4) The rocks in the former are very irregularly inclined, and sometimes are quite horizontal as in some places in Okinawa-jima. Thus the Tertiary of the northern half of the Riukiu Curve is probabry later than that of the southern half which belongs to Miocene. In this curve the deposits later than the Tertiaries are only the raised coral reefs, with Recent coral-reefs, sand &c. As mentioned in my "note on the raised coral reefs in the Riukiu Curve" (1901), the raised reefs are horizontally bedded, but quite irregularly distributed, thus showing that the folding of the Curve had taken place before the building of the reefs. The distinct zones of rocks, (namely, the inner neovolcanic, the median Palæozoic, and the outer Tertiary,) coincide with those in the Peninsula of Malacca, the Andaman Isles and the Nicobar Isles in the Indian Ocean, with the Banda Isles, in

the East Indies, and with the Lesser Antilles in the West Indies. Though our islands have been only slightly disturbed by volcanic action in the southern part, yet they show the type of folded mountain with parallel structure, as already treated in the preliminary note of Prof. Kotô, and ascertained by my own observations in nearly all the islands of the interesting Riukiu Curve.

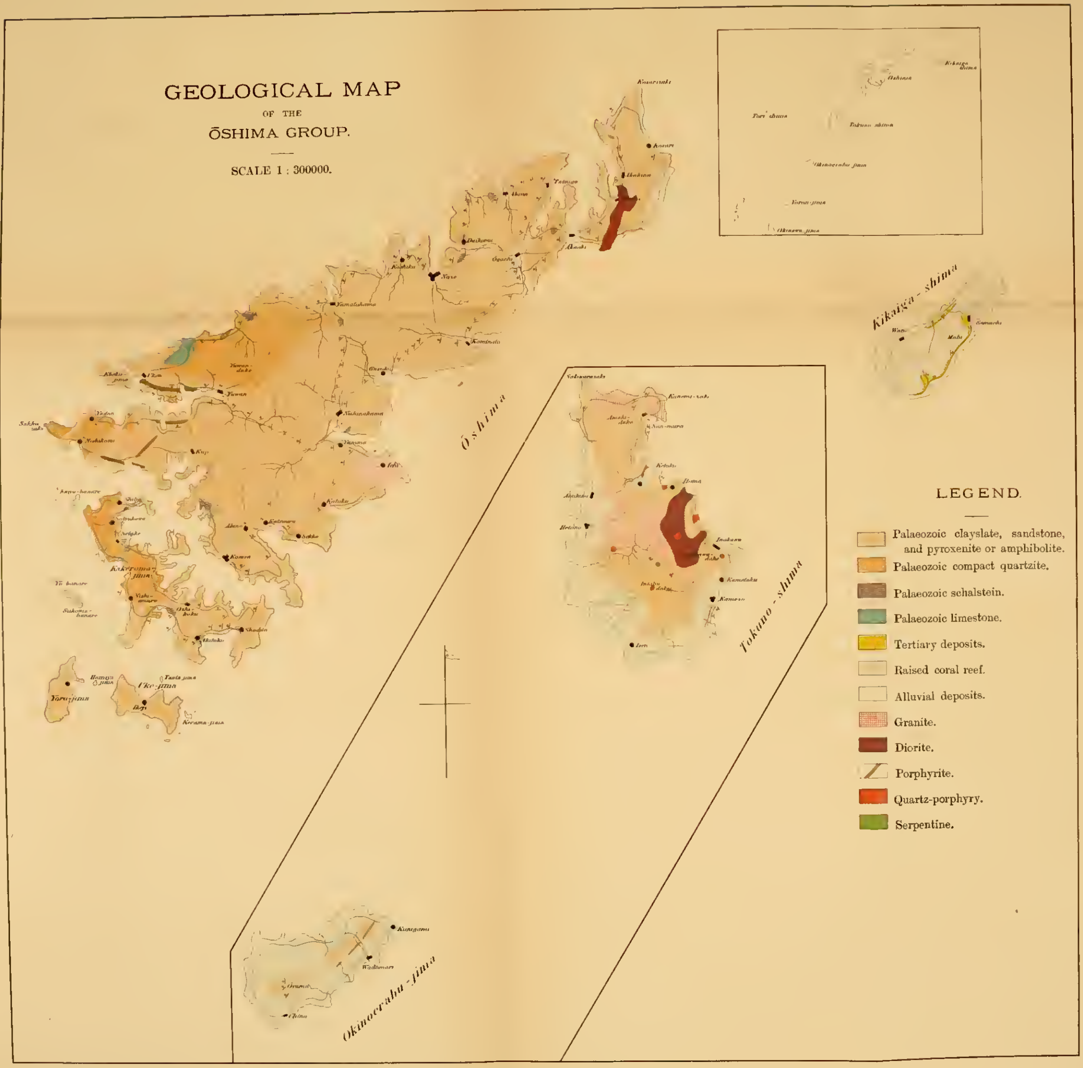
March 1901.

PLATE I.

Plate I.

Geological Map of the Ōshima Group.

Scale 1 : 300.000.



Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE II.

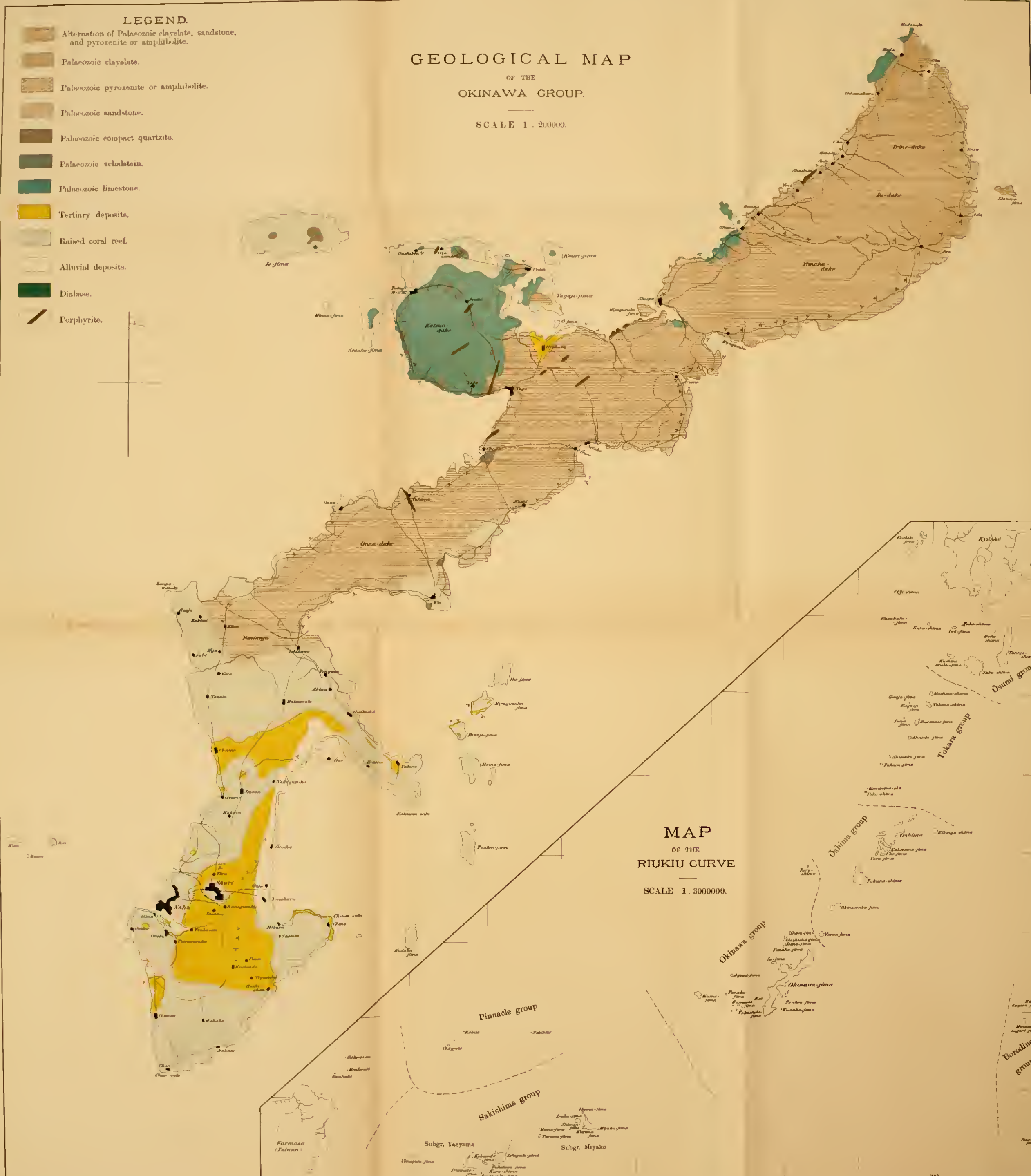
Plate II.

Map of the Riukiu Curve.

Scale 1 : 3.000.000.

Geological Map of the Okinawa Group (excluding the Kerama and Iheya Subgroups, Kume-jima, Tonaki-jima, Aguni-jima, and Tori-shima)

Scale 1 : 200.000.



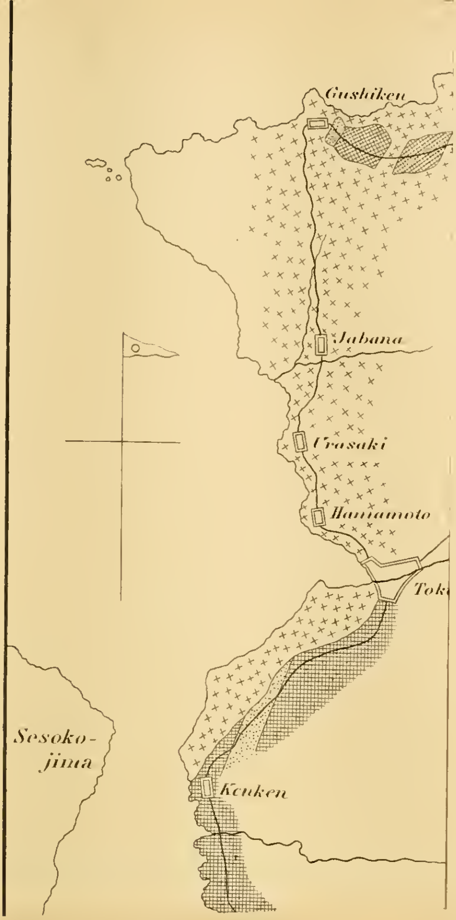
Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE III.

Plate III.

Geological Map of the Yaeyama Subgroup (excluding Yonaguni-jima.)

Scale 1 : 200.000.



ERRATUM.

The explanations for the Plates III & IV are alternated.

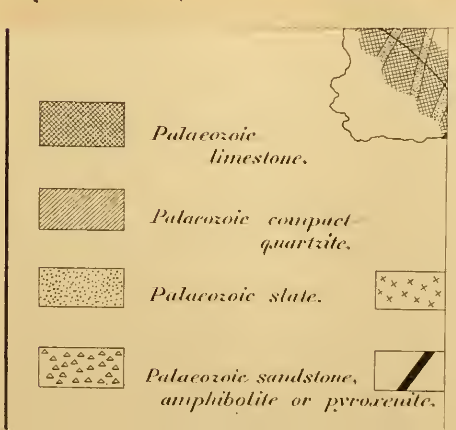


Plate III.

Geological Map of the Yaeyama Subgroup (excluding Yonaguni-jima.)

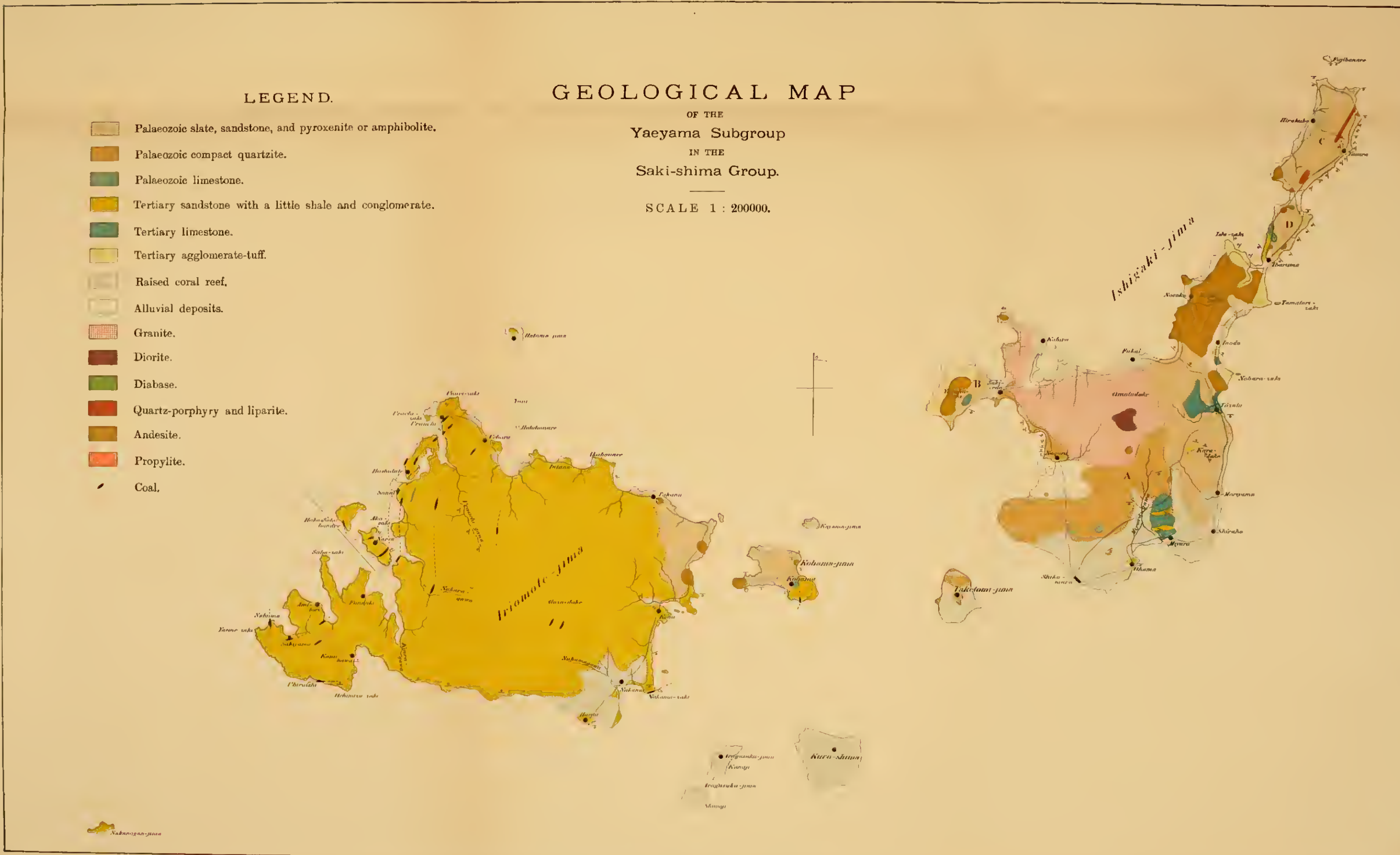
Scale 1 : 200.000.

Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE IV.

Plate IV.

Geological Exposures observed in the Motobu Region, Okinawa-jima.



Yoshiwara, Geologic Structure of the Riukiu Curve.

PLATE V.

Plate V.

Fig. 1.—View of Ishigaki-jima, seen from Taketomi-jima.

- ✓ Yarabu peninsula (andesite, agglomerate-tuff, and Palæozoic slate, sandstone &c.)
- ✓✓ Omotodake (granite).
- ✓✓✓ Bannā-and Maise-dake (Palæozoic compact quartzite &c.).
- ✓✓✓✓ Region near Kwannon (Palæozoic compact quartzite).
- ✓✓✓✓✓ Region near Shikamura (raised coral reefs).

Fig. 2.—View of the Northern Side of Yonaguni-jima.

- ✓ Raised coral reefs.
- ✓✓ Tertiary sandstone.

Fig. 1.

Fig. 2.

Yoshiwara, Geologic Structure of the Riukiu Curve.

CONTENTS.

JOURNAL OF THE COLLEGE OF SCIENCE, IMPERIAL UNIVERSITY,
TOKYO, JAPAN.
VOL. XVI., ARTICLE 3.

Corallinæ veræ Japonicæ,

By

K. YENDO, Rigakushi.

Botanical Institute, College of Science, Tokyo Imperial University.

With 7 Plates.

Introduction.

During these five years spent in the collection of Marine Algae along the coast of northern and middle Japan, I have paid special attention to the family Corallinaceae. I took for my own study the subfamily Corallinae and sent the specimens of Melobesiae to Mr. M. Foslie of Norway, begging his collaboration on the group. He detected among them a dozen species, several of which are new to science. His papers based on the study of this material have been published in Det Kgl. Norske Videnskabers Selskabs Skripter[1]. In the Corallinae I examined as many as thirty species, which are enumerated in the present work. Lately a few species of Corallinae have been sent to our Institute from Loochoo and elsewhere in the

1). New or critical Calcareous Algae. 1899, No. 5.
Five new Calcareous Algae. 1900, No. 3.
Revised systematical survey of the Melobesiae. 1900, No. 5.

southern part of Japan, but they are not included here, being left for future publication.

During the past fifty years, the Marine Algae of Japan have attracted the notice of several European botanists, and the literature relating to them is not inconsiderable. Yet the calcareous algae seem to have been neglected by these collectors and investigators, only a few species being mentioned in their writings.

Georg von Martens enumerated[1)] 6 species of Corallinae which were collected on the coast of Japan and its vicinity. Afterwards a few more species were reported from Formosa collected by Warburg and determined by Heydrich[2)]. De Toni[3)], Wildeman[4)], and others compiled a list of Algae reported from Japan and Eastern Asia, in which 11 species of Corallinae are assigned to Japan.

Among these 11 species, some are limited to Formosa and Loochoo, upon which I do not touch at this time, and of others it has been impossible for me to verify the existence. Cheilosporum (Arthrocardia) frondescens, Corallina (?) filicula, and Corallina officinalis v. mediterranea, reported by Martens to have been collected at Yokohama, are especially doubtful to me. When we set these members aside, we have left only two or three species which I feel justified in incorporating in the present studies.

The figures in the accompanying plates have been made from sections of the dried materials, if not otherwise stated. The author found Perény's fluid answers best for the decalcification of the material. In the case of more delicate plants acetic-sublimate or Flemming's fluid may also be used. For staining he preferred

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1) Preussische Expedition nach Ostasien. Tange. 1866—1868.

2) Heydrich: Beitrage zur Kenntuiss der Algenflora von Ostasien. Hedwigia, Bd. XXXIII. 1894.

3) De Toni: Phyceae Japonicae Novae. 1898.

4) Wildeman: Prodrome de la flore Algologique des Indes Neélandaises. 1897.

Böhmer's Hematoxylin for 20–40 minutes, and then Fuchsin (0.3 gr. in 100 cc. 50% alc.) for one hour. The genicular cells and spores stain in red, and the cellwall in purple. Decalcifying, fixing and staining at the same time with Schneider's Aceto-carmin, and afterwards staining the section with Böhmer's Hematoxylin also answers pretty well.

The writer wishes to express his hearty thanks to Prof. Dr. J. Matsumura under whose direction he executed the work ; also to Mr. M. Foslie who generously spared him the specimens which he got from the late Prof. Areschoug, Le Jollis and others ; and to Dr. K. Okamura, Prof. Dr. K. Miyabe, Major Th. Reinbold, and Prof. Dr. M. Miyoshi, for their kind gifts of specimens and for valuable advice.

CORALLINAE VERAE JAPONICAE.

Amiphiroa, Lamx.

1. Amphiroa valonioides, sp. nov.

Pl. I. fig. 1—3 : Pl. IV. fig. 1.

Fronde pulvinato-cæspitosa; ramis paucis, patentibus, lateralibus, pseudo- sympodialibus vel irregulariter dichotomis ; articulis exacte cylindraceis, equicrassis, 0.2–0.3 mm. latis, 0.6–0.8 mm. longis, apice obtusis ; geniculis superioribus obsoletis, inferioribus articulorum diametrum æquantibus ; conceptaculis verrucæformibus.

The articuli are homogeneously cylindrical, measuring 0.2–0.3 mm. in diameter and 0.6–0.8 mm. in length, becoming a little thicker and shorter toward the base. Branches are few in number and generally proceed laterally from the top of an articulus without geniculum, in a sympodial manner.

The conceptacles are ellipsoidal warty protuberances, often covering the whole surface of an articulus. The genicula are very insignificant especially at the upper portions, owing to the durability of the cortical part after they have been completed (Pl. I. fig. 3).

I can not not find any appropriate description referable to the present plant, although it has some resemblance to *Amphiroa setacea*, *Kütz* : but the character " ramulis oppositis plerumque tuberculatis patentibus " is hardly applicable to our plant.

Found in the sublittoral region at the coast of the Prov. of

Hiuga in the summer of 1900; At Misaki, in the autumn of the same year.

2. Amphiroa rigida, Lamx.

Pl. I. fig. 5–6: Pl. IV. fig. 4.

Amphiroa rigida, Lamx. Polyp. Coral. p. 297. Pl. II. fig. I.
Aresch: in J. Ag. Spec. Alg. II. p. 533.
Zanard: Icon. Phyc. Adr. III. p. 79. T. 99. B.
Kütz: Spec. Alg. p. 701.
Id: Tab. Phyc. VIII. T. 42. fig. IV.
Solms: Corall. p. 6.
Hauck: Meeresalgen. p. 276. fig. 113.
? A. lucida. Lamx. l. c. p. 297.
A. verruculosa. Kütz. Phyc. Gen. p. 387.
Id: Spec. Alg. p. 700.
Id: Tab. Phyc. VIII. Taf. 39. fig. II.
Solms: Corall. p. 8.
A. cladoniæformis, Menegh. Kütz: Spec. Alg. p. 700.
Id: Tab. Phyc. VIII. T. 42.
A. spina, Kütz. Phyc. Gen. p. 387.
Id: Spec. Alg. p. 700.
Id: Tab. Phyc. VIII. Pl. 41. fig. 1.
A. amethystina, Zanard. Kütz: Spec. Alg. p. 700.
A. irregularis, Kütz. Phyc. Gen. p. 389.
Id: Spec. Alg. p. 700
Id: Tab. Phyc. VIII. Taf. 41. III.
A. inordinata, Zanard: Icon. Phyc. Adr. III. 79.
Aresch: in J. Ag. Spec. Alg. p. 542.
Kütz: Spec. Alg. p. 701.

This species, common in the Gulf of Naples, is rather rare in Japan ; being restricted to the southern coast of Kiushū Island and hitherto not found in the main island (Honshū) : in the low side mark and below.

3. Amphiroa cretacea, Endl.

Pl. I. fig. 4 : Pl. IV. fig. 2.

Fronde lapidescente, irregulariter di-trichatome ramosa, superne attenuata ; ramis ramulisque divaricato-deflexis, saepe insignis ; articulis 4–8 mm. longis, 2–3 mm. latis ; geniculis sublineæformibus ; conceptaculis verrucæformibus prominentibus diametro 0.8 mm.

Corallina cretacea, Post. et Rupr. Ill. Alg. p. 2. Taf. XL. fig. 104.

Amphiroa cretacea, Endl.

Aresch : in J. Ag. spec. Alg. II p. 533.

Kütz : spec. Alg. p. 701.

Id : Tab. Phyc. VIII. Taf. 45.

Harv : Ner. Bor. Amer. p. 86.

? A. californica, J. E. Tilden. Amer. Alg. IV. no. 301.

f. rosariformis. nov. form. Pl. IV. fig. 3.

Ramis longis, sursum attenuatis, articulis brevissimis diametrum subæquantibus rotundis.

It is stout and robust in its appearance and attains the height of 5–12 cm. ; the colour is rosy purple while living. The articuli are thoroughly cylindrical, except the ramiferous ones which are sub-compressed cuneate. The conceptacles are large, measuring 0.8 mm. in diameter.

A side branch is often found prolonged to form a sort of fastening

disc, by which it attaches to a pebble or a rock as shown in the photograph (fig. 2). This is remarkable in the case of *f. rosariformis.*

A dwarfed form, found in the southern limit of the cold current, is very similar in its appearance to the well grown forms of *Amphiroa rigida*, from which, however, can be distinguished by having the large conceptacles and the rosy purple tint.

This plant is one of the flora of the cold Siberian current. The current washes the whole coast of Hokkaido (Yesso) and runs southward as far as Kinkwa-san Island in the prov. of Rikuzen. So also the plant is distributed. It is generally found deeper than 2 feet below the low tide mark, usually where a few other plants grow. Prov. Rikuzen : Hakodate : Otaru : Rishiri Island. *f. rosariformis* is hitherto known only from Kaifu, a rocky coast in the western side of the main island (Honshū).

4. Amphiroa ephedræa, (Lamk.) Aresch.

Pl. I. fig. 7–10 : Pl. IV. fig. 5–8.

Fronde elata regulariter dichotoma, flabellata, sursum attenuato-tereti vel compresso-subdilatata ; ramis ramulisque patentibus ; articulis inferioribus brevioribus, superioribus diametro 3plo—5plo longioribus ; geniculis inferioribus diametrum subæquantibus, superioribus brevioribus ; conceptaculis numerosis.

β. fronde inferne tereti vel subtereti, superne sensim compressa vel subcomplanata.

Corallina ephedraea, Lamk. Mem. Mus. II. p. 238.

Amphiroa ephedræa, Aresch. b. in J. Ag. Spec. Alg. II. p. 534.

A. Gaillonii, Lamx. Polyp. Coral. p. 298. t XI. 3.

Kütz : Tab. Phyc. VIII. Taf. 47. I.
A. Gueuzii, Harv. Ner. Austr. p. 95.
Kütz : Tab. Phyc. VIII. Taf. 48. I.
A. ephedræa, Lamx. Sonder : in Frag. Phyt. Austr. XI. Supl.

γ. fronde pulvinato-caespitosa, inferne tereti vel subtereti, superne subattenuata ; articulis cylindraceis, ultimis mucronatis.

Forma β has its articuli cylindrical at the lower portions, somewhat compressed in the middle, but the terminal articuli are long cylindrical, subattenuating toward the apex. Dense tufts are sometimes found, and sometimes isolated form ; in the latter case the frond generally assumes a larger size (Pl. IV. fig. 5).

The second form γ always occurs in tufts, the terminal articuli being homogeneousely cylindrical often attenuating toward the base.

Although I refer our plant to the present species, the original descriptions are not satisfactorily applicable to it. In ours the genicula are rather small when compared with a specimen ex Herb. Areschoug. Nevertheless, A. ephedræa, (Lamk.) Aresch. seems to be, at any rate, a variable and inconstant species ; and there is no little danger to claim an independent position for our plant. *Amphiroa Gaillonii, Lamx.* is mentioned in the list of Algae collected by Martens[1] ; and a fragmental specimen doubtedly identified to it was collected in the "Challenger Expedition"[2], on the shore of Oshima harbour near the Kiushū Island. These specimens might have been either of the above mentioned forms.

Boshū ; Misaki ; Shimoda ; Prov. of Hiuga ; Prov. of Mikawa : in the low side marks and below.

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1) Preussische Expedition nach Ostasien. Tange. p. 131.
2) Dickie : Journ. of Linn. Soc. Bot. vol. 15. p. 450.

5. Amphiroa zonata, sp. nov.

Pl. I. fig. 11–14 : Pl. IV. fig. 9.

Fronde 2–5 cm. alta. tereti-compressa, latitudine equali vel sursum latiore. dichotoma ; ramis ramulisque patentibus ; articulis infimis brevissimis, mediis 0.8–1.0 mm. latis, 4.0–6.0 mm. longis, supermis compressis linearibus, apice latioribus obtusis. pulcherrimis transversis striis ; geniculis inferioribus diametrum aequantibus, superioribus poriformibus ; conceptaculis verrucaeformibus oblongis.

The present plant is distinguished from others by having regularly and "indirectly"[1] dichotomous, flabellate branches. The articuli of the middle and upper portions are compressed with round edges, and the terminal articuli have always remarkable transverse striations. In a dried specimen we see a deep transverse furrow parallel to the apical margin, in the place of the terminal striation. This furrow is of a secondary importance owing to the contraction of the part in the exsiccation.

In the vicinity of the Marine Laboratory at Misaki, we find two forms of plants referable to this species. One is always found at the littoral region and the other in 5–20 feet deep water. The former has more patent branches of rosy purple colour, and the terminal articuli are much more compressed : the latter is of greyish purple, with the branches more fastigiate and the terminal articuli less compressed. But the general characters are similar in several respects and sharp

1) In the dichotomous branching of Corallinae, I distinguish three types, viz :—

I. Indirect dichotomy : articulus diverging before it had a geniculum.

II. Direct dichotomy : articulus having two genicula at the end, from which the successive articuli arise.

III. Decussate dichotomy : one order of dichotomy in the plane at right angles to that of the adjacent order.

These expressions would be repeated in the present work.

boundary is hard to draw. The shallow water form has very often the terminal articuli cylindrical and approaches to a form of the preceding species.

Usually found at the depth of 5–20 ft. below low water mark : the shallow water form, however. often found at the low tide mark. Misaki : Shimoda : Sunosaki.

6. Amphiroa echigoensis, sp. nov.

Pl. I. fig. 15-16 : Pl. IV. fig. 10.

Fronde subcompressa latitudine equali, dichotoma : articulis nfimis cylindraceis, brevissimis, mediis subcompressis equierassis, 0.6–0.9 mm. latis, 3–5 mm. longis, superioribus plus minus compressis, haud transverse striatis, ultimis apice rotundis ; geniculis diametrum æquantibus majoribusque ; conceptaculis minutis sub-prominentibus.

The articuli are somewhat compressed except near the base. Their breadth is homogeneous throughout the entire frond, measuring 0.6–0.9 mm. in diameter. But those in the ultimate portion are slightly compressed and broader. The genicula are equal in breadth ito the articuli looking as the brown bands on the dried specimens. In this species neither the transverse striation nor the furrow near the apical margins can be seen.

This species undoubtedly stands near to the former, but differs widely in its internal structures ; the cortical part consists of several layers of the parallelopedal cells, compactly arranged in an anticlinal direction, thickly covering the zonal arrangement of the periclinal cells ; conceptacles are slightly prominent but frosted over the whole surface of the articuli. It has some resemblance with *Amphiroa algeriensis, Kütz.* and *Amp. exilis, Harv.* Yet differs from the former by

the mode of ramification, and from the latter by its remarkable genicula.

Found on a rock at sublittoral region: not very common. Kaifu: Matsushima.

7. Amphiroa dilatata, Lamx.

Pl. I. fig. 17–21: Pl. V. fig. 4.

Amphiroa dilatata, Lamx. Polyp. Coral. p. 299.
Harv: Ner. Austr. p. 97.
Kütz: Spec. Alg. p. 703.
Id: Tab. Phyc. VIII. Tab. 50. fig. III.
De Toni: Phyc. Jap. Nov. p. 41.
Aresch: in J. Ag. Spec. Alg. II. p. 536.
Amphiroa galaxauroides, Sond. Plant Preiss. vol. II. p. 188.
Martens: Preus. Exp. n. Ostasien. p. 29.
Kütz: Spec. Alg. p. 704.
Id: Tab. Phyc. VIII. Taf. 51. fig. I.

The large genicula on the lowermost portion give the frond a flexible character: this circumstance, no doubt, is the cause of the frond's being always found spreading radially while living. The conceptacles are found mostly on the shaded side of the fronds. They are sometimes densely frosted over an articulus, and sometimes arranged in two irregular rows in the periclinal direction. The diagramatic as well as more minute details of a meridional section of an articulus of the former case are shown in the plate. (Pl. I. fig. 17 and 18).

About the transverse striations Areschong does not give any particular description. Kützing remarks "non striae" in the diag-

nosis of *A. dilatata*, and "transversim et subtiliter zonatis" in that of *A. galaxauroides* (Spec. Alg. l.c.) Our plant has always plain transverse zones and much more applies to the latter than to the former.

Martens enumerates *A. galaxauroides* in the list l.c. He does not acknowledge the reduction of the species by Areschong on the ground that his plant has the articuli "alle flach und ziemlich gleich breit," while in *A. dilatata* "sind die untersten Glieder stielrund." I could not find any species of *Amphiroa* whose articuli were flattened already at the base, provided that it had been a complete specimen.

At the depth of 4–10 ft. below low water mark. Misaki: Sanosaki: Shimoda: Prov. of Hiuga.

8. Amphiroa pusilla, sp. nov.

Pl. I. fig. 22–23: Pl. V. fig. 11–13.

Fronde 1.5–3.0 cm. alta, decumbenti saepe erecta, ima basi subtereti, superne compressa, di-trichotoma; articulis infimis subteretibus, mediis compressis 1.0–1.5 mm. latis 3.0–4.0 mm. longis, superioribus complanatis vel planis sursum attenuatis, ecostatis, non transverse striatis; geniculis brevibus inferioribus, angustioribus superioribus; conceptaculis numerosissimis.

This species stands very near to *Amphiroa dilatata*, *Lamx.* But the articuli are always much more rounded and in every proportion small. The attenuity of the terminal articuli, ending finally in a blunt point, is its special character. Conceptacles are generally found on the shaded surface, but in the erect form on both surfaces.

In the low water mark: Misaki.

9. Amphiroa misakiensis, sp. nov.

Pl. I. fig. 24–25 : pl. VI. fig. 1.

Fronde ima basi tereti, superne complanata, di-trichotoma ; ramis patentibus ; articulis infimis subteretibus, mediis lato- vel obovato-cuneatis subplanis, tum saepe attenuatis, superioribus foliiformibus obovato-clavatis vel palmatis medio subcostato-elevatis, marginibus plus minus utrinque undulatis ; geniculis inferioribus latitudine 3-plo brevioribus, superioribus subpunctiformibus; conceptaculis.........

It has thin and short articuli at the basal portion ; but the upper articuli are very broad and foliaceous, giving rise to several flat ramuli so as to form a digitate branch. The ventral surface of the articuli is convex and the other slightly canaliculated at both margins—the cross section, therefore, lunate. No transverse striation could be seen.

It is not very common, only a few specimens have been collected at low tide mark : Misaki.

10. Amphiroa canaliculata, Martens.

Pl. I. fig. 26 : Pl. IV. fig. 14–15.

Fronde maxima, basi tereti, superne compresso-complanata, irregulariter dichotoma ; articulis compresis lineari-oblongis, dorso convexis, ventre bi-canaliculatis, ultimis attenuatis ; geniculis brevissimis ; conceptaculis dorso numerosissimis.

Amphiroa canaliculata, Martens. Preus. Exp. n. Ostas. p. 28. Taf. VI.

Our specimen is somewhat fragmentary and the entire aspect can not be fully known : but the convexity of the dorsal surface and canaliculation in the ventral very well coincide with Marten's description. One peculiarity in this plant is that the flat articuli may give rise at their edges to a lot of tiny branchlets. This character is cleary shown in Marten's plate as well as in the accompanying photograph.

By trawling on the coast of the Prov. of Kazusa ; rare. (Dr. K. Okamura).

11. Amphiroa declinata, sp. nov.

Pl. I. fig. 29 : Pl. VI. fig. 4.

Fronde declinata, ima basi tereti, superne compresso-complanata, di-trichotoma ; ramis patentibus, pinnatis saepe bipinnatis ; pinnis pinnulisque sursum sensim brevioribus ; articulis inferioribus cylindraceis diametro sesqui-vel 2-plo longioribus, mediis subscutiformibus vel hexagonis, apicalibus rotundis, pinnarum pinnularumque sublineæ-scutiformibus ; geniculis linearibus ; conceptaculis numerosissimis conicis in marginibus articulorum insitis.

The articuli in the middle and the upper portions are always compressed, more or less plainly costated. The branches are regularly pinnated with their general outlines rhomboidal. The fronds measure 4–6 cm. in length ; the average articuli 1.5–2.5 mm. wide, 2.5–3.0 mm. long. They grow upright at the beginning but soon spread horizontally with the upper parts bending downwards. The conceptacles, 0.5 mm. in diameter, are found mostly growing in a row on the edge of an articulus, pointing obliquely toward the ventral side.

Below low tide mark. Misaki : Prov. of Hiuga : Prov. of Echigo : Prov. of Wakasa (Mr. R. Tsuge) : Matsushima Bay.

12. Amphiroa crassissima, sp. nov.

Pl. I. fig. 27–28 : Pl. V. fig. 5–6.

Fronde crassissima, ima basi tereti superne comprsso-complanata, di-trichotoma, irregulariter pinnatis ; articulis inferioribus cylindraceis diametrum æquantibus, mediis scutiformibus vel obtrapezoidibus, superioribus compressis plus minus costatis, oblongo-obcordatis vel sagittatis, lobis patentibus ; articulis ultimis clavatis ovatisque vel sagittatis ; apice albis, levite transverse striatis ; geniculis inferioribus linearibus superioribus obscuris ; conceptaculis paucis in marginibus articulorum insitis.

The fronds measure 5–7 cm. high spreading widely upwards. By the virtues of the thick articuli and the insignificant genicula, the fronds assume a very robust appearance. The terminal articuli are often digitated, and sometimes the lobes of a sagittate articulus are prolonged into lacineated broad wings. The fertile articuli are irregularly cylindrical or sublinear with one or two rows of conical conceptacles.

Below low tide mark. Misaki : Shimoda : Prov. of Boshū.

13. Amphiroa aberrans, sp. nov.

Pl. II. fig. 1–5 : Pl. V. fig. 1–3.

Fronde maxima, ima basi subtereti, superne compressa, di-trichotoma ; ramis ramulisque oppositis patentibus ; articulis infimis teretibus, inferioribus compressis scutiformibus, medio elevatis, utrinque adpressis, mediis superioribusque eramiferis sagittatis plus minus costatis, lobis projectis, articulis ultimis obovatis ; geniculis linearibus ;

conceptaculis aliis in mediis articulorum aliis saepe in apicibus loborum insitis.

The present species is large and beautiful plant often attaining the height of 12–20 cm. The articuli are sagittated with compressed and broad wings, without any indication of the zonal striation. Conceptacles are mostly found on the surfaces of the flat articuli, not seldom immersed in the projected angles of the articuli.

It is in this plant that the decussate branches are often proliferated from the surface of an articulus (fig. 1 & 2. Pl. II). In normal condition the proliferations are few in number and short in length. But when they are numerous and luxuriant the frond assumes quite a different form from the normal one ; and not seldom another species of *Corallinae* grows together with those aberrant branches, making the frond much more perplexing.

The decussate branches have the articuli normal but often linear, sometimes very broad spathulate ones. In the latter cases the terminal articuli are generally thin, broad and fan-shaped, concave as a watchglass.

I was not able to find any description satisfactorily referable to this plant. The figures of *Corallina frondescens*, *C. gomphonemacea* and *C. flabellata var.* in Kützing's Tab. Phyc. (Pl. 59. II ; Pl. 63. I ; Pl. 63. II) seem to have some relations with the plant in question. But the original descriptions of the above mentioned species are impossible to be applied to our plant.

It is rather common in the middle parts of Japan, on the Pacific coast as well as on the Japan Sea side : found in the sublittoral region often covering a good area of a rock. Misaki : Bōshū : Shimoda : Prov. of Hiuga : Prov. of Wakasa (Mr. R. Tsuge) : Prov. of Echigo.

Cheilosporum, (Aresch.) Schmitz.

1. Cheilosporum anceps, (Kütz).

Pl. II. fig. 6–8 : Pl. VI. fig. 2.

Fronde tenuiore, gracile, basi tereti, mox compresso-complanata, substipitata, densissime di-trichotoma ; articulis omnibus subcostatis, infimis cylindraceis diametro 0.5–1.0 mm., mediis eramiferis scutiformibus vel obcordatis, superioribus ramulorumque linearibus vel obcordatis vel sagittatis, lobis saepe laxe prominentibus ; conceptaculis in apicibus vel mediis loborum tumescentibus ; geniculis brevissimis.

Corallina anceps. Kütz. Phyc. Gen. p. 388.

Id : Tab. Phyc. Taf. 62. fig. I.

Id : Spec. Alg. p. 708.

The articuli in this species are highly variable in their form and size ; those of the branches as well as the upper portions are generally linear, measuring 0.5–1.0 mm. in breadth and 5.0–7.5 mm. in length ; those of the middle portion, cordate, reniforme or sagittate. The lobes of the sagittate articuli sometimes attain to 1. cm in length, very often giving rise to long branchlets at their apexes. The apical articuli are very small, cylindrical, linear or obovate in the shape. We have in many cases small protuberances at the top of the superior articuli and not seldom of the middle portion. These are abnormal decussate branches and may develope into the branches with cordate or sagittate articuli. Although the articuli are thus variable in the form, every lower end of them is always pointed, leaving a narrow space to admit the small geniculum. So the movement of the articuli is slightly restrained and the whole frond is extremely delicate.

Conceptacles one to three in each articulus ; in the middle or at the tops of the lobes, or the both cases taking places at the same time.

At low side mark : Hakodate.

var. modesta, nov. var.

Pl. II. fig. 9 : Pl. VI. fig. 3.

Fronde tenui ; articulis obcordatis vel sagittatis, longitudine inter genicula distantiam loborum subæquante vel sesquibreviori, ultimis rotundatis vel ovatis.

The form of the articuli in this variety is nearly constant ; the extraordinary prominent lobes of the sagittate articuli or the linearly prolonged ones are not found in this plant.

At low tide mark. Hakodate : Kaifu (Prov. of Echigo).

2. Cheilosporum yessoense, sp. nov.

Pl. II. fig. 12–13 : Pl. VI. fig. 5.

Fronde robusta, multicipiti, basi subtereti, mox compresso-complanata nudiusculo-stipitata, irregulariter dichotoma vel prolifera, basibus articulorum prominentibus ; articulis inferioribus scutiformibus utrinque compressis, superioribus approximatis obcordatis vel obreniformibus lobis patentibus rotundis adpressis, apicalibus flabellatis ; geniculis brevissimis ; conceptaculis in margine loborum superiori articulorum immersis vel in mediis loborum tumescentibus.

f. angusta. Pl. II. fig. 14–15 : Pl. VI. fig. 6.

Fronde angustiore, articulis obcordatis vel sagittatis, conceptaculis in mediis loborum tumescentibus.

In the typical form the articuli are compactly arranged and their form is highly regular: those of the upper portions have the lobes projecting obliquely upwards but gently turning into transversal direction. The former articuli, therefore, assume a form just like the wings of an acer fruit or a clock key; and the maximum breadth measures 4–6 mm., the inter-genicular distance 1.5–2.0 mm. The outline of a branch is without exceptional spathulate. The lower end, or the pedicel, as it were, of an upper or middle articulus is always prominent as in a bamboo node, but gently disappearing as we trace downwards. The conceptacles are generally immersed in the upper margins of the lobes.

The *f. angusta* has a similar character, but narrower articuli: The breadth measures 2.0–2.5 mm., the inter-genicular distance 1.5–2.0 mm. The conceptacles are immersed in the middle parts of the lobes and seldom at the apexes.

The description of *Amphiroa chiloensis*, *Dcne.*, *Amp. prolifera*, *Lamx.* etc., are with slight modifications applicable to *f. angusta*. But they are not sharply defined and we are afraid of confusing them more and more by applying our plant to either of them until we have had an authentic specimen to refer to.

Both typical and the narrow form have been collected at Hakodate; the former was also found in the Prov. of Boshū (Dr. K. Okamura): below low water mark.

3. Cheilosporum californicum, (Dcne.)?

Pl. II. fig 10: Pl. VI. fig. 8.

Amphiroa californica, Dcne. classif. d. Alg. et Cor. p. 112.
Kütz: Spec. Alg. p. 704.

Aresch : in J. Ag. Spec. Alg. II. p. 542.
? Harv : Ner. Bor. Amer. p. 86.

I have a collection of plants of somewhat dwarfed form. They are like *Cheilosporum yessoense* but much smaller in all respects, measuring neary 2 cm. in height and the other parts in proportion. They closely resemble the specimen of *Cheil.* (*Amphiroa*) *californicum*, (*Dcne.*) which is *ex herbario* of Dr. Farlow and kept in the herbarium of our Institute.

We can not say much about the present species as our specimens seem to be somewhat abnormal and incomplete. All we can here say is to mention a doubtful plant referable to the present species, collected on the Pacific coast of Japan.

Low tide mark. Prov. of Boshū.

4. Cheilosporum latissimum, sp. nov.

Pl. II. fig. 16–17 : Pl. VI. fig. 7.

Fronde latissima, robusta. multicipiti, basi tereti, mox compresso-complanata. irregulariter ramosa ; articulis approximatis sagittatis lobis patentibus apice truncatis, plus minus subcostato-elevatis, longitudine inter genicula distantiam loborum 2 plo—3 plo breviori, basibus articulorum prominentibus ; conceptaculis binis vel quattuor in apicibus loborum immersis.

The plant attains to the height of 4–6 cm. with a short stipe. The articuli in the middle and upper portion are extremely thin and brittle, and compactly arranged : the maximum breadth measuring 6–8 mm. and the inter-genicular distance 2–5 mm. Two to four, often five conceptacles are found in one articulus at the upper portions.

They are immersed in the wings, with the opening pores at the external margins, ending at the projecting points.

Cast aschore on the coast of Prov. of Kazusa (Dr. K. Okamura).

5. Cheilosporum maximum, sp. nov.

Pl. II. fig. 18–19: Pl. VI. fig. 9.

Fronde maxima, robusta, multicipiti, ima basi tereti longe stipitata, superne compresso-complanata, irregulariter laterali-ramosa, pectinato-pinnata; articulis stipitis subcylindraceis diametro aequi-longioribus, pinniferis hexagonis vel truncatis subcostatis; pinnis approximatis vel imbricatis, mediis inferioribusque linearibus, superioribus spathulatis; conceptaculis in apicibus pinnarum immersis vel per medios articulos prominentibus.

This plant, one of the most beautiful on our coast, is very common on the shore of the Sagami Bay. The fronds attain the height of 12–15 cm. with rather long stipes. The articuli at the basal part are short and cylindrical which gently flatten upwards and becomes provided with pinnule at each corner of the upper angles. The pinnae are flat and very regular in their shape, just like a pectoral fin of a common fish. But in the upper portions they are a little changed, being sometimes linear, spathulate, often bifurcating at the apex.

Conceptacles are generally solitarily immersed at the apexes of the pinnules, but not seldom in an axial articulus.

It is necessary to notice that this plant is a species somewhat apart from the ordinary *Cheilosporum*. *Cheilosporum*, strictly speaking, has no pinnules. Nevertheless, we often find the enormously prolonged and finally jointed lobes in those plants which belongs to the

genuine *Cheilosporum*. Our plant should be taken as an extreme case of this modification.

It is an inhabitant of the sublittoral region, often covering the whole surface of a reef to the exclusion of other plants. Prov. of Boshū : Prov. of Kazusa : Misaki : Shimoda.

Corallina, Lamx.

1. Corallina yenoshimensis, sp. nov.

Pl. II. 21–24 : Pl. VII. fig. 2.

Fronde decumbente, caespitosa, fastigiata, regulariter dichotoma, axillis acutis, ramis suberectis saepe apice subinflatis ; ramulis moniliformibus tenuissimis a basi proliferis : articulis ominibus compressis vel ancipitibus, ramiferis subcuneatis, eramiferis sublinearibus, dichotomiis superioribus ultimisque conceptaculiferis ; conceptaculis ovatis.

The frond is fastigiate and regularly dichotomous, the terminal portion more or less inflated. Articuli are compressed and measure 1.0–1.5 mm. in length, and 0.6–1.0 mm. in width : whole size of frond 2.0–2.5 cm. The terminal articuli as well as the horns are always linear and blunt. The conceptacles are oval or elliptical, slightly bulging out at the end of upper articuli. We find always in this plant some slender moniliform branchlets proliferating from the basal articuli.

Sublittoral region. Hakodate : Yenoshima (Dr. K. Okamura).

2. Corallina nipponica, sp. nov.

Pl. II. gg. 20 : Pl. VII. fig. 1.

Fronde erecta, caespitosa, dichotoma, axillis acutis, ramis erectis ;

articulis mediis superioribusque cylindraceis, inferioribus compressis ancipitibus truncatis. dichotomiis superioribus ultimisque conceptaculiferis ; conceptaculis subclavatis cornibus brevissimis.

The present plant bears some resemblance to *Cor. rubens, L.* But it is much thicker and has a more robust appearance. The cylindrical articuli are 0.6–0.8 mm. long and 0.18–0.2 mm. wide ; the lower articuli being broader and shorter, and compressed. The conceptacles have generally blunt short horns of a single joint.

Low water mark. Kaifu.

3. **Corallina adhærens,** (Lamx.) mut. strict.

Pl. III. fig. 4 : Pl. VII. fig. 5.

Fronde irregulariter decussato-dichotoma, vel paniculata, ramis divaricatis intertextis. capillaceis ; articulis cylindraceis diametro 6 plo—10 plo longioribus, ultimis cylindraceis subattenuatis, conceptaculis urnæformibus apicalibus.

Jania adhærens, Lamx. Polyp. Coral. p. 270.
Kütz : Spec. Alg. p. 710.
Aresch : In. J. Ag. Spec. Alg II. p. 559.
Corallina adhaerens, Kütz. Tab. Phyc. VIII. t. 83. p.p.
Heydrich : Beit. z. Kennt. (Hedwig. Bd. 33. p. 301.)
De Toni : Phyc. Nov. Jap. p. 42.

It has slender capillary articuli measuring 0.08 mm. in diameter and 0.5–0.8 mm. in length. The branches are irregularly decussate dichotomous, with ultimate articuli slightly attenuated. This way of branching makes the frond in a massive tuft ; and moreover lots of the decussate branches form fastening discs at their ends to fuse

together with the branches in contact. Thus a spongy mass of calcareous network are often found.

The original description of the present species is at once applicable to both the present and the next species. These two species have several characters worthy enought to separate one another.

Found in tufts, usually epiphytic on other algae, in the sublittoral region. Prov. of Boshū : Misaki : Shimoda : Prov. of Hiuga.

4. Corallina decussato-dichotoma, sp. nov.

Pl. III. fig. 1–3 : Pl. VII. fig. 3–4.

Fronde fragile, decussato-dichotoma, ramis divaricatis intertextis, articulis cylindraceis diametro 2 plo—5 plo longioribus ultimis cylindraceis acutis ; conceptaculis urnæformibus, cornibus longioribus.

Corallina adhærens Kütz. Tab. Phyc. VIII. t. 88. p.p.

The articuli in the present plant are thicker than in the preceding species, measuring 0.2–0.9 mm. in length and and 0.1–0.15 mm. in diameter. Conceptacles are rarely found ; and if present, they are provided with long, many articulated horns. The length of the articuli is variable according to the habit of the plant : When it grows epiphytically upon an alga, the articuli are comparatively long, and the mass is somewhat loose.

On rocks or epiphytic on other algae at low water mark. Misaki : Prov. of Boshū : Prov. of Hiuga.

5. Corallina arborescens, sp. nov.

Pl. III. fig. 5 : Pl. VII. fig. 5.

Fronde 1 cm. alta, erecta, regulariter dichotoma ; ramis patentibus

sursum attenuatis; articulis inferioribus compressis ancipitibus, mediis superioribusque subcompressis diametro 3–4plo longioribus, ultimis linearibus vel scutiformibus; geniculis constrictis; conceptaculis..............

The lower articuli are compressed and truncated; the middle ones measure 0.6–0.8 mm. long, 0.15–0.2 mm. wide.

Epiphytic on other alga, at low tide mark. Kaifu: Akashi (Prof. J. Matsumura).

6. Corallina radiata, sp. nov.

Pl. III, fig. 6: Pl. VII fig. 7.

Fronde minima, flabellata, ramis radiato-fastigiatis, regulariter dichotoma; articulis infimis teretiusculis mox compresso-complanatis, lineari-clavatis, diametro 2plo–3plo longioribus; conceptaculis.........

The articuli are flat and linear, and measure hardly 0.3 mm. in width, 0.8 mm. in length. Several fronds arise from a common disc with the basal articuli apparently similar in shape and size to those of the other portions. The disc is round, and more or less convex on the upper surface, reminding us *Cor. Lenormandiana, Grun.* (*Cor. nana, Lenorm.*). No conceptacle is yet found.

Found epiphytic upon *Cystophora*, *Sargassum* or other brown algae, forming a rosy spot. Prov. of Shima (Mr. K. Tani): Kamakura: Misaki: Prov. of Kii.

7. Corallina ungulata, sp. nov.

Pl. III. fig. 7–8: Pl. VII. fig. 8.

Fronde tenuissima, compressa, dichotoma, ramis divaricatis

subintertextis ; articulis inæqualibus sursum attenuatis et brevioribus, mediis superioribusque cylindraceis omnibus diametro 8–13 plo longioribus, ultimis latis unguliformibus vel cylindraceis, dichotomiis superioribus ultimisque conceptaculiferis ; conceptaculis urnæformibus cornibus simplicibus.

f. brevior, f. nov. Pl. III. fig. 9. Pl. VII. fig. 9.

Fronde tenuiore, articulis brevioribus diametro 2–3plo longioribus, superioribus subclavatis, ultimis unguliformibus vel globosis.

The typical form has a similar habit to *Cor. adhærens*, *Lamx.* in forming a large mass of spongy network. *f. brevior* is more robust than the type in virtue of the shortness of the articuli. These two, however, approach one another and sharp boundary is impossible to draw.

The ultimate articuli of a sterile frond have a special character. They are broad and compressed at the apical margin, cylindrical at the base : the apparent shape, therefore, is like a horse's hoof, after which the plant has been named. This character is owing to the peculiar mode of ramification. An articulus tends to ramify when it is yet very short ; or one articulus is prolonged after it has given forth the successive articuli. The matured plant, as a consequence, has a few articuli of this sort and becomes difficult to separate from the loose form of *Cor. decussato-dichotoma*.

The typical form has been found in the Prov. of Wakasa (Mr. R. Tsuge), and at Misaki ; *f. brevior*, in the Prov. of Bōshū : both at low water mark.

8. Corallina sp.

Pl. III. fig. 10.

A tiny plant irregularly dichotomous, with patent branches ;

craniferous articuli cylindrical, ramiferous clavate, 4–5 times longer than breadth: Conceptacles at the upper and the ultimate dichotomous points.

The present plant has its all branches fertile and disables us to determine the species. Found epiphytic on *Cheilosporum anceps*, (*Kütz.*) *var. modesta* collected at Kaifu.

9. Corallina officinalis, L.

Pl. III. fig. 11–13 : Pl. VII. fig. 10–13.

Corallina officinalis, L. Fauna Suec. n. 2234.
Harv : Phyc. Brit. Pl. 222.
Aresch : in J. Ag. Spec. Alg. II. p. 562.
Kütz : Spec. Alg. p. 705.
Id : Tab. Phyc. VIII. Taf. 66–68.
Kjell : Alg. of Arc. Sea. p. 86.
Hauck : Meeresalgen. p. 281.
Cor. densa, Kütz : Spec. Alg. p. 705.
Cor. spathulifera. Kütz. Spec. Alg. p. 709.
Id : Tab. Phyc. VIII. T. 65.
Cor. nana. Zanard. Icon. Phyc. Adr. III. T. 55.
Kütz : Spec. Alg. p. 709.
Id : Tab. Phyc. VIII. T. 86.
Aresch : in J. Ag. Spec. Alg. II. p. 564.

α: Pl. III. fig. 11 : Pl. VII. fig. 10. fronde brevi, tereti; articulis ramorum compressiusculis clavatis, pinnarum cylindraceis vel linearibus, ultimis cylindraceis saepe laciniatis.

β: Pl. III. fig. 12 : Pl. VII. fig. 11. fronde crassiore, robusta; articulis ramorum subcylindraceis clavatis diametro sesqui—2 plo

longioribus, pinnarum cylindraceis. elongatis, tenuissimis, ultimis cylindraceis.

γ : Pl. III. fig. 13 : Pl. VII. fig. 12. fronde crassissima dense fastigiata ; articulis ramorum subcomplanatis, mediis subcostatis, clavatis vel truncatis, pinnarum pinnularumque subcylindraceis, ultimis subcompressis.

δ : Pl. VII. fig. 13. fronde majore, parce ramosa ; articulis infimis cylindraceis diametrum subæquantibus, axium ramorumque subcompressis, oblongo-obovatis vel subclavatis, pinnarum linearibus compresso-complanatis subcostato-elevatis, ultimis compressis ovatis.

The form *α* is widely distributed in the middle part of Japan as well as in Hokkaido (Yesso). It is found densely covering large patches of rocks from the high water mark to 2–3 feet below the surface. Under the influence of surrounding conditions it is generally bleached into a dirty white or greenish colour. It attains hardly to 2–4 cm. in height with the axial articuli 1 mm. long, 0.5 mm. or less wide ; the pinnae being much thinner. Very often a laciniated articulus is found at the top of a branch.

The second form *β* accords in several respects with *f. flexilis* of Kjellman. But our plant is smaller than his, measuring only 4–8 cm. in height ; its articuli are cylindrical throughout the whole part of the frond, gently attenuated toward the apex ; the axial articuli measure 1.5 mm. in length and 1. mm. in width ; the uppermost ones being only as thick as a brittle.

The form *c* of Areschong in J. Ag. Spec. Alg. l. c. might prove the same as our form *γ*. They accord very well on the points remarked by him, except in regards to the shape of the ramiferous axial articli, which are much more compressed and more or less costated in our specimens.

The form δ is a comparatively large plant. Its raniferous axial articuli are subcompressed and clavate; and those of pinnae much more flattened and edged: pinnules are mostly delicate and cylindrical. No conceptacle yet found. This form is somewhat uncertain of its position, as it wants the propagating organ. Yet, the general appearance shows to have a close relation to the present species.

α, common along the whole coast of Japan: β. Hakodate; Otaru; Matsushima: γ, Hakodate: δ, Hakodate; Prov. of Wakasa (Mr. R. Tsuge).

10. Corallina pilulifera, Post. et Rupr.

Pl. III. fig. 14–16: Pl. VII. fig. 14–16.

Corallina pilulifera, Post. et Rupr. Illustr. Alg. p. 20. t. XL. fig. 101.

Ruprecht: Tange d. Och. Meer. p. 344.

Kütz: Tab. Phyc. Taf. 64. fig. 1.

Aresch: in J. Ag. Spec. Alg. II. p. 563.

f. Sororia, Rupr. Pl. III. fig. 15: pl. VII. fig. 15.

Corallina pilulifera, Post. et Rupr. f. Sororia, Rupr. Tange d. Och. Meer. p. 344.

f. filiformis, Rupr. Pl. III. fig. 14: pl. VII. fig 14.

Corallina pilulifera, Post. et Rupr. f. filiformis, Rupr. Tange. d. Och. Meer. p. 344.

? Kütz: Tab. Phyc. VIII. Taf. 87. fig. II.

f. intermedia, f. nov. Pl. III. fig. 16: Pl. VII. fig. 16.

Articulis ramorum truncatis vel deltoideo-obcordatis angulis non projectis, pinnarum brevissimis, subcylindraceis vel clavatis, ultimis obovatis compressis.

Corallina pilulifera is undoubtedly a variable plant seeming to approach *Cor. officinalis, L.* on one side and *Cor. squamata, Ellis et Sol.* on the other. Nevertheless, the descriptions of the forms given by Ruprecht l.c. sharply define the differences between them, two of which were quite applicable to our plants. *f. typica, Rupr.* could not be found in our coast, and I found another form hitherto not yet described, *f. intermedia.*

f. Sororia is a comparatively robust plant, easily separable from the other members. It is always found decumbent: the ventral surface of the articuli are highly elevated while the upper remain flat. This is characteristic of this form. When it has assumed a more delicate appearances, it becomes almost impossible to distinguish from *f. filiformis.*

f. filiformis is a very slender plant, with the characteristic long pedunculated conceptacles. The articuli of the main branches have no projecting shoulders. It has always laciniated broad articuli at the apexes of some branches, which was a character, according to the author, to separate *Cor. arbuscula* from *Cor. pilulifera.*

f. intermedia is just an intermediate form between the above mentioned two. In a case where all the pinnules were conceptaculiferous we are almost unable to separate it from *Cor. officinalis, L.* As has been already noticed by Ruprecht, the terminal articuli, complanated obovate, must not be neglected to distinguish from the latter. Besides, there may be found two minute cylindrical pinnules at each side of the conceptacles so as to form five articuli starting from one articulus. This character is rarely found in *Cor. officinalis, L.*

Found at the low tide mark, forming a dense tuft on rocks; also in tide pools. *f. Sororia*: Hakodate; Otaru; Matsushima; Misaki. *f. filiformis*: Prov. of Boshū; Wakanoura (Prof. J. Matsumura); Misaki; Yenoshima; Hakodate. *f. intermedia*: Hakodate.

11. Corallina squamata, Ellis et Sol.

Pl. III. fig. 17 : Pl. VII. fig. 17.

Corallina squamata, Ellis et Sol. p. 117.
Lamarck : Mem. du Mus. II. p. 232.
Lamx : Polyp. Cor. p. 287.
Kütz : Spec. Alg. p. 706.
Id : Tab. Phyc. VIII. Taf. 76.
Aresch : in J. Ag. Spec. Alg. II. p. 567.
Cor. squamata, Park. Harv : Phyc. Brit. Pl. 201.
Cor. compressa, Lamk. Mem. du Mus. II. p. 233.
Lamx : Polyp. Cor. p. 286.
Kütz : Spec. Alg. p. 706.
Amphiroa heterarthra, Trevis. Flora. no. 27. p. 416.

Among the collection from Hakodate, I have a plant densely tufted upon the shell of a muscle. The upper portion of its fronds is simple rosariform. On comparing it with the specimen kindly given me by Mr. M. Foslie, which is a part of a plant he got from the late Prof. Areschoug, I found our plant to be an abnormal form of the present species. There is no uncertainty in mentioning *Cor. squamata* as an inhabitant of our coast.

At low tide mark, also in pools : Hakodate.

12. Corallina sessilis, sp. nov.

Pl. III. fig. 18 : Pl. VII. fig. 18.

Fronde complanata, nudiusculo-stipitata, pinnato-ramosa ; articulis inferioribus teretibus, superioribus ramorumque compressis

hexagonalibus, truncatis vel scutiformibus subcostato-elevatis, pinnularum brevibus subcylindraceis sursum attenuatis ; conceptaculis compressis sessilibus in apice pinnarum pinnularumque immersis, vel saepe brevissime pedunculatis.

It is comparatively small plant, measuring 3–5 cm. in height. The main articuli are evidently ribbed on the ventral surfaces and measure 1. mm. in the maximum breadth, with nearly equal length. The conceptacles are either sessil when they are inserted in the pinnae, or with short compressed peduncles when they take places of the pinnules. They are rather compressed, and two or three are often found in one pinna having the aspect of those of *Cheilosporum latissimum*. cfr. Pl. II fig. 16.

At low tide mark : Hakodate.

13. Corallina kaifuensis, sp. nov.

Pl. III. fig. 19 : Pl. VII. fig. 19.

Fronde irregulariter dichotome ramosa ; ramis pinnatis, circumscriptione rhomboidalibus, pinnis sursum sensim brevioribus ; articulis inferioribus subteretibus, ramiferis truncatis vel clavatis subcompressis, pinnarum tenuioribus cylindraceis vel linearibus ; conceptaculis terminalibus majoribus obovatis pedunculatis.

The frond measures 2–5 cm. in height with the axial and the apical articuli somewhat compressed. Those of the pinnae are generally cylindrical and thin, measuring 0.5–0.75 mm. in length. Conceptacle is found at the top of the terminal articulus ef each pinnule.

At low tide mark : Kaifu.

14. Corallina confusa, sp. nov.

Pl. III. fig. 20 : pl. VII. fig. 20.

Fronde tenuissima, subtrichotoma, irregulariter pinnata ; articulis infimis teretibus, superioribus compresso-complanatis, ramorum cuneatis vel deltoideis, pinnarum subimbricatis linearibus vel lanceolatis sursum dilatatis ; geniculis punctiformibus ; conceptaculis globosis longe pedunculatis vel sessilibus in apice agglomeratis.

It is hardly more than 3 cm. high, with all of its parts thin and weak. The conceptacles are either sessile or pedunculated and are found at the apical portion of the frond agglomerating in a confused manner, hence the name. The genicula are comparatively large seeming as the brownish spots over the fronds.

It covers large patches of rocks at high tide mark. At the first sight we perceive a granular mass on a rock, which after examing is known to be the agglomerated conceptacles wholy covering the vegetative portion of the fronds. Hakodate.

June, 1901.

Botanical Institute,

Imperial University, Tokyo.

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PLATE I.

Plate I.

Figs. 1—3. *Amphiroa valonioides.*

1 and 2. Two forms of the fronds, × Ca. 7.

3. A longitudinal section through a branching point: The cortical parts arround the genicula are not yet broken off. Zeiss. 2 × BB.

Fig. 4. *Amphiroa cretacea, Endl.*

A diagramatic figure of a longitudinal section of a frond: the medullary portion is bounded with a dotted line; a conceptacle bulging out from the cortical part.

Figs. 5—6. *Amphiroa rigida, Lamx.*

5. A diagramatic figure of a longitudinal section of a frond; six conceptacles are seen immersed in the cortical part. Zeiss. 2 × AA.

6. The geniculum of the same section more magnified; the genicular cells are intertwixed at the middle portion of the geniculum.

Figs. 7—9. *Amphiroa ephedraea, Lamk.* β.

7. An apical part of a branch of the isolated form. × Ca. $2\frac{1}{2}$.

8. The same of the tuft form. × Ca. $2\frac{1}{2}$.

9. A portion of a longitudinal section of an articulus of the isolated form; from fresh material, decalcified and fixed with chromic acid 4% sea water solution. Zeiss. 2 × DD.

Fig. 10. *Amphiroa ephedraea, Lamk.* γ.

An apical part of a branch. × Ca. $2\frac{1}{2}$.

Figs. 11—14. *Amphiroa zonata.*

11. A portion of branch magnified: The terminal furrows and the transverse zones are clearly seen.

12. A portion of a meridional section of an articulus: observe that the cortical layer is very thin. Zeiss. 4 × AA.

13. A longitudinal section of the terminal portion of a branch. The cellular arrangements are much disturbed at the furrow, and the

incompletely calcified cells are dissolved away during the process. Zeiss. 4 × AA.

14. A diagramatic figure of a cross section of an articulus; the boundary between the cortical layer and medullary part is shown with a dotted line. Zeiss 2 × AA.

Figs. 15—16. *Amphiroa echigoensis.*

15. A portion of a longitudinal section of an articulus bearing a conceptacle: the cortical cells are arranged in the anticlinal direction forming a thick layer. Zeiss. 4 × BB.

16. A diagramatic figure of the cross section of an articulus, compare with Fig. 14. Zeiss. 2 × AA.

Figs, 17—21. *Amphiroa dilatata, Lamx.*

17. Diagramatic figure of a meridional section of a fertile articulus, with numerous conceptacles. Zeiss. 2 × AA.

18. A part of the same magnified. The periclinal cells are interwoven like a mat. From a fresh material. Zeiss. 4 × BB.

19. A part of the cross section of an old geniculum. Zeiss. 4 × DD.

20. A longitudinal section of the same: transverse thickenings of the walls are highly developed, with connecting canals between newly formed intercellular spaces. Zeiss 4 × DD.

21. An upper portion of a frond, showing zonal arrangement of the periclinal cells; the space bounded with a dotted line indicates the genicular area; this area stains metachromatically with some staining reagents after decalcification. Zeiss 2 × AA.

Figs. 22—23. *Amphiroa pusilla.*

22. A cross section of a frond through a conceptacle; from a fresh material. Zeiss. 2 × BB.

23. A diagramatic figure of a cross section of an articulus.

Figs. 24—25. *Amphiroa misakiensis.*

24 and 25. Diagramatic figures of the cross sections of the articuli.

Fig. 26. *Amphiroa canaliculata Mart.*

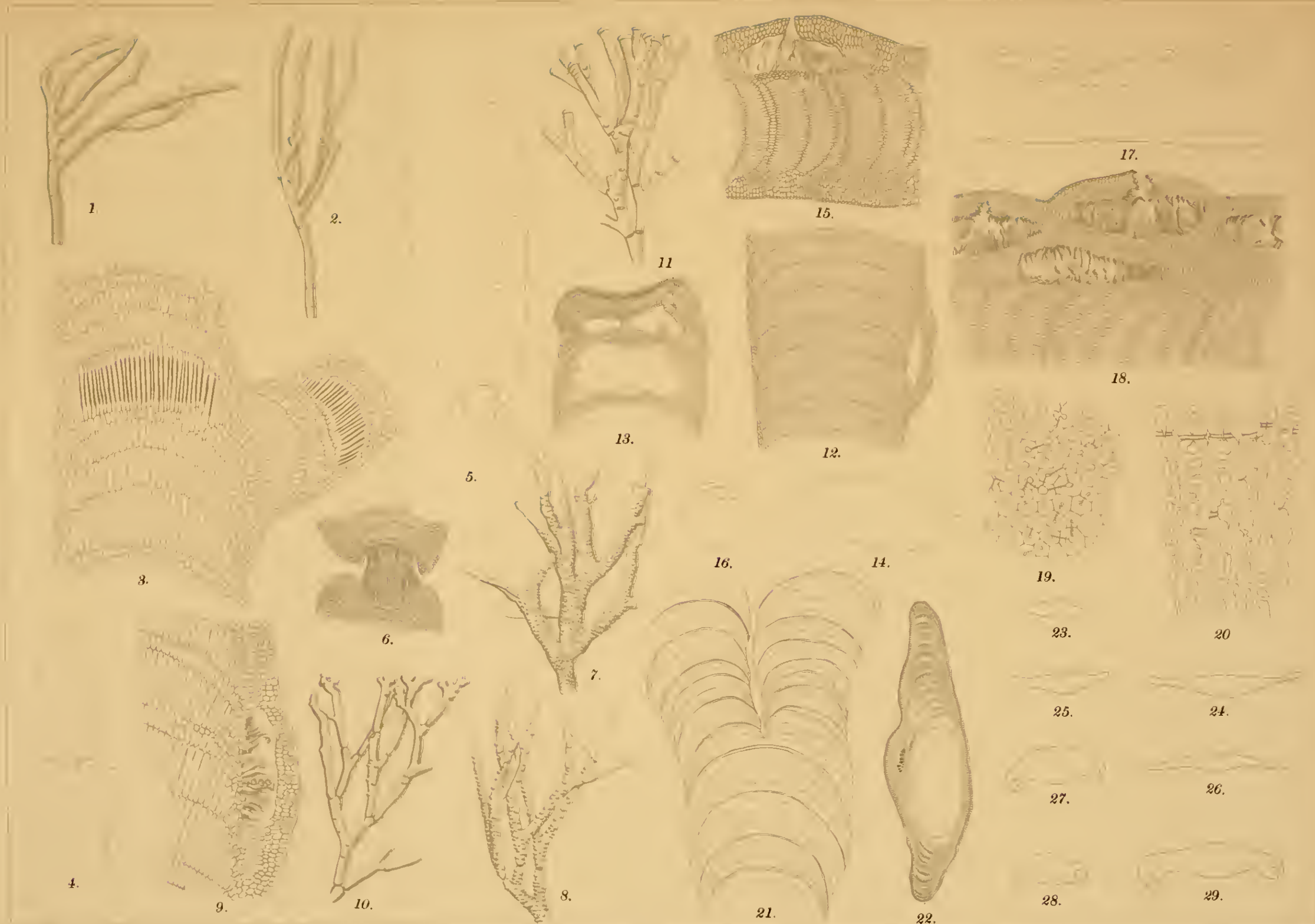
A diagramatic figure of a cross section of an articulus. Compare the ribs, depressions and canaliculations in 23, 24, 25 and 26. In *Amp. pussila* the dorsal surface is costated, while in the others the ventral is much more costated: in *Amp. misakiensis* it is canaliculated in the dorsal while in *Amp. canaliculata* in the ventral side.

Figs. 27—28. *Amphiroa crassissima.*

Diagramatic figures of the cross sections of the articuli. × Ca. 7.

Fig. 29. *Amphiroa declinata.*

A diagramatic figure of a cross section of an articulus. × Ca. 7. Compare 27, 28 and 29; also observe that the conceptacles are projecting obliquely toward the ventral side.



K. Yendo del.

Yendo—Corallinae verae Japonicae.

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PLATE II.

Plate II.

Figs. 1—5. *Amphiroa aberrans.*

1 and 2. Portions of some abnormal branches, magnified; cylindrical proliferations and the spathulate branches are to be seen.

3. A meridional section of a solitary conceptacle, which is very often found immersed in the top a projected lobe. Zeiss. 4 × BB.

4. Cross section of an articulus bearing two conceptacles. Zeiss. 4 × BB.

5. A longitudinal section of a young frond with a geniculum; a part of the frond of a *Lithothamnion* is deep in the substratum; the geniculum is perhaps formed of several zones of periclinal cells, but only continuous filaments being observed in the section. Prepared by grinding. Zeiss. 2 × BB.

Figs. 6—8. *Cheilosporum anceps, (Kütz.).*

6. A portion of a conceptaculiferous branch. × Ca. 3.

7. Meridional section of a projected angle bearing a conceptacle; the periclinal cells are somewhat undulating. Zeiss 2 × BB.

8. A diagramatic figure of the cross section of an articulus bearing three concaptacles. × Ca. 7.

Fig. 9. *Cheilosparum anceps, (Kütz.). var. modesta.*

A cross section of an articulus for comparison with the typical species. × Ca. 7.

Figs. 10—11. *Cheilosporum californicum, (Dcne.)!*

10. A portion of branch. × Ca. 3.

11. Cross section of an articulus. × Ca. 7. Compare with 8 and 9.

Figs. 12—13. *Cheilosporum yessoense.*

12. An upper portion of a frond bearing conceptacles in the top of the wings. × Ca. 3.

13. Diagramatic figure of the cross section of an articulus. × Ca. 7.

Figs. 14—15. *Cheilosporum yessoense. f. angusta.*

14. A portion of a branch with cenceptecles; some are immersed in the top

of the wings, some in the middle of an articulus ; three conceptacles have their roofs broken off, and piercing holes are seen as its result. × Ca. 3.

15. A diagramatic figure of the cross section of an articulus. × Ca. 7.

Figs. 16—17. *Cheilosporum latissimum.*

16. Some of the fertile articuli ; each articulus bears four conceptacles in the figure, immersed in the external margins of the wings. × Ca. 3.

17. Diagramatic figure of the cross section of an articulus. × Ca. 7.

Compare 13, 15 and 17 ; and observe the proportions of the thickness and breadth of the articuli.

Figs. 18—19. *Cheilosporum maximum.*

18. A portion of a fertile branch with normal conceptacles, magnified.

19. Cross section of an articulus bearing two conceptacles on its surface. Their origins are deep in the medullary portion.

Fig. 20. *Corallina nipponica.*

A portion of a fertile branch. × Ca. 7.

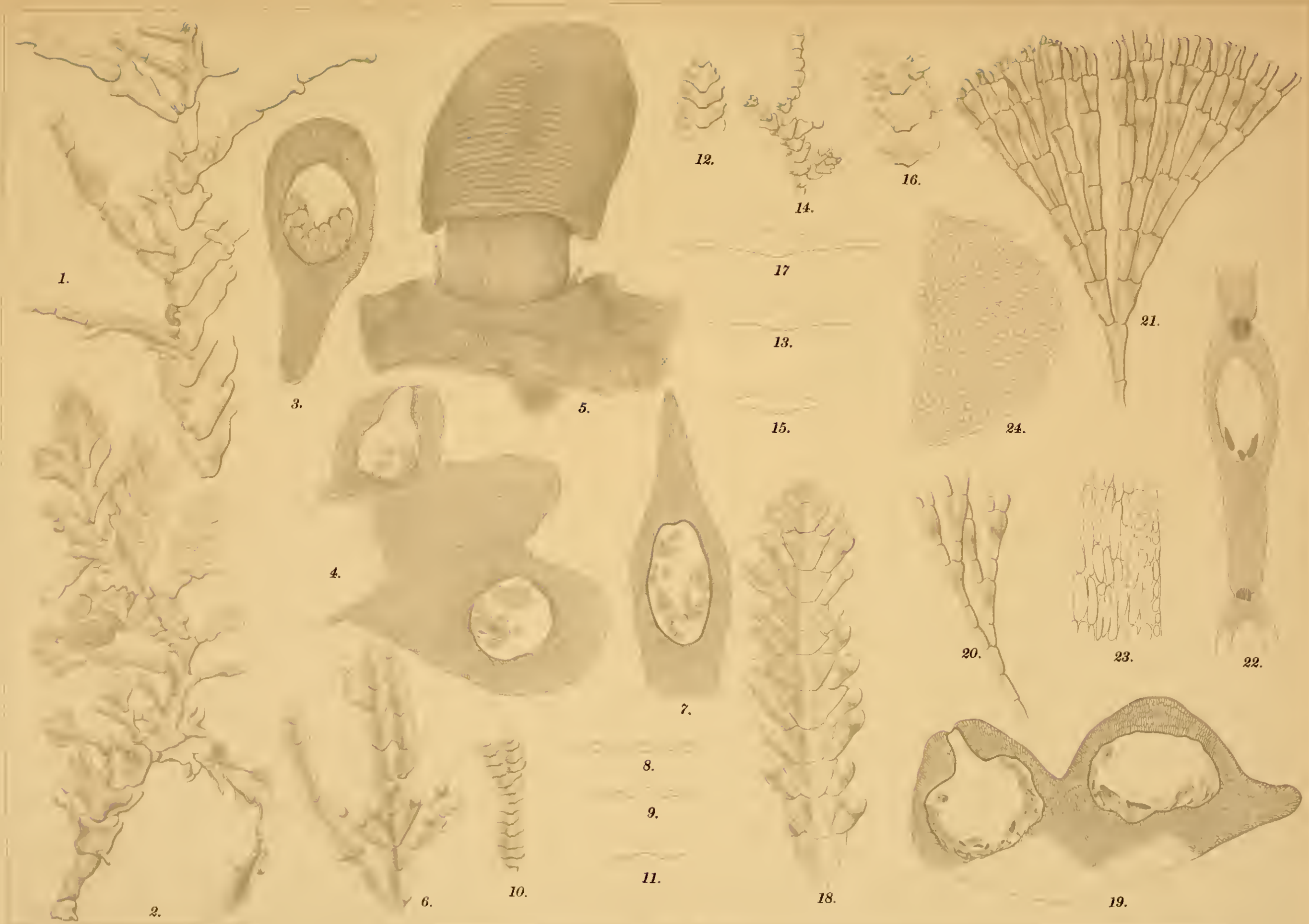
Figs. 21—24. *Corallina yenoshimensis.*

21. A portion of a fertile branch. × Ca. 7.

22. Diagramatic figure of the meridional section of a branch through a conceptacle. Zeiss. 2 × AA.

23. A portion of a longitudinal section of an articulus to show the cortical cells and the periclinal cells ; the latter have the large communicating canals in the cellwalls. Zeiss. 4 × DD.

24. A portion of a cross section of the same. Zeiss. 2 × DD.



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Yendo—Corallinae verae Japonicae.

PLATE III.

Plate III.

Figs. 1—3. *Corallina decussato-dichotoma.*

1. A portion of a branch attacked by *Choreonema Thureti, Schm.*, with its conceptacles frosted on the branches. × Ca. 10.
2. A portion of a branch without parasite. × Ca. 10.
3. Longitudinal section of a branch through a geniculum; the zonal arrangement of the periclinal cells is not clear in this species; *a*, portions of the penetrated frond of the parasite stained in the same degree as the genicular cells. Zeiss 2 × DD.

Fig. 4. *Corallina adhærens, Lamx.*

A portion of branch. × Ca. 10.

Fig. 5. *Corallina arborescens.*

A portion of branch. × Ca. 10.

Fig. 6. *Corallina radiata.*

A portion of branch. × Ca. 10.

Figs. 7—8. *Corallina ungulata.*

7. A portion of a sterile branch, the characteristic articuli are shown at the upper portions, × Ca. 10.
8. A fertile branch, with conceptacles at the terminal and the diverging points. × Ca. 10.

Fig. 9. *Corallina ungulata, f. brevior.*

A portion of branch. × Ca. 10.

Fig. 10. *Corallina sp.*

The fertile frond, without any sterile branch. × Ca. 10.

Figs. 11—13. *Corallina officinalis, L.*

11. A portion of the branch of α. × Ca. 4.
12. do. of β. × Ca. 4.
13. do. of γ. × Ca. 4.

Figs. 14—16. *Corallina pilulifera, Post. et Rupr.*

14. A branch of *f. filiformis Rupr.* × Ca. 7.

15. do. of *f. Sororia Rupr.* × Ca. 7.

16. do. of *f. intermedia* × Ca. 7.

Fig. 17. *Corallina squamata, Ellis et Sol.*

An abnormal branch with moniliform branches at the upper part. × Ca. 7.

Fig. 18. *Corallina sessilis.*

A portion of fertile branch. × Ca. 7.

Fig. 19. *Corallina kaifuensis.*

A portion of fertile branch, the conceptacles in the terminal articuli of the pinnules. × Ca. 7.

Fig. 20. *Corallina confusa.*

A portion of fertile branch. × Ca. 7.

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PLATE IV.

The figures in the following plates are all in natural size of the fronds.

Plate IV.

Fig. 1. *Amphiroa valonioides.*

Fig. 2. *Amphiroa cretacea, Endl.*

Fig. 3. *Amphiroa cretacea, Endl. f. rosariformis.*

Fig. 4. *Amphiroa rigida, Lamx.*

Figs. 5—6. *Amphiroa ephedræa, Lamk. β.*

Figs. 7—8. *Amphiroa ephedræa, Lamk. γ.*

Fig. 9. *Amphiroa zonata.*

Fig. 10. *Amphiroa echigoensis.*

Figs. 11—13. *Amphiroa pusilla.*

11. Decumbent frond from the ventral side, conceptacles are seen frosting on this side.
12. do. from the dorsal side.
13. A frond in vertical habit; the conceptacles are seen on both sides.

Figs. 14—15. *Amphiroa canaliculata, Mart.*

View from the dorsal side: conceptacles are seen frosting on this side.

15. View from the ventral side: two canals are seen running along the edges of the articuli.

R. Uchiyama et K. Yendo Photo.

Yendo—*Corallinae verae Japonicae.*

PLATE V.

Plate V.

Figs. 1—3. *Amphiroa aberrans.*

1. The abnormal forms, with proliferating decussate branches; an *Amphiroa* of different species is growing together with *Amphiroa aberrans* in the right hand tuft.
2. A frond in less aberrant form; broad, spathulate and thin articuli occurring at the apical portion of the frond.
3. Normal frond.

Fig. 4. *Amphiroa dilatata, Lamx.*

View from the dorsal side; some of the branches are overturned to show the conceptacles growing on the ventral side.

Figs. 5—6. *Amphiroa crassissima.*

5. The sterile fronds.
6. The fertile fronds; the right hand branch is seen from dorsal side, and the middle branch from ventral. Observe that the conceptacles are on the ventral margins of the articuli.

R. Uchiyama et K. Yendo Photo.

Yendo—Corallinae verae Japonicae.

PLATE VI.

Plate VI.

Fig. 1. *Amphiroa misakiensis.*

Fig. 2. *Cheilosporum anceps, (Kütz.).*

Fig. 3. *Cheilosporum anceps, (Kütz.) var. modesta.*

Fig. 4. *Amphiroa declinata.*

View from the dorsal side ; a branch in the lower side is overturned to show the attachment of the conceptacles at the ventral margins of the articuli.

Fig. 5. *Cheilosporum yessoense.*

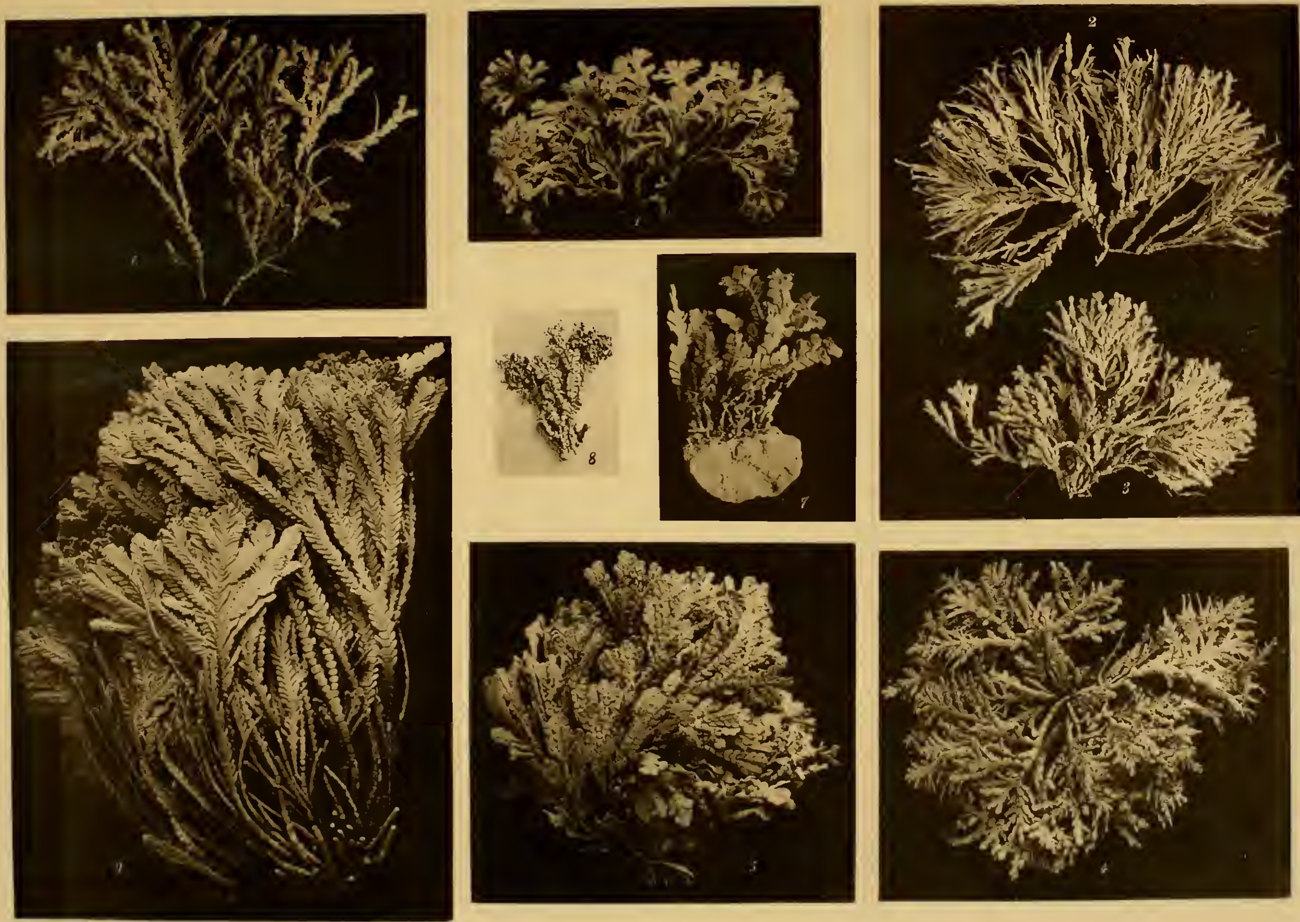
Fig. 6. *Cheilosporum yessoense. f. angusta.*

Fig. 7. *Cheilosporum latissimum.*

Fig. 8. *Cheilosporum californicum, (Dcne.)?*

Fig. 9. *Cheilosporum maximum.*

A branch is seen having conceptacles both immersed at the top of pinnae and bulged out on the surface of the articuli.



R. Uchiyama et K. Yendo Photo

Yendo—Corallinae verae Japonicae.

PLATE VII.

Plate VII.

Fig. 1. *Corallina nipponica.*

Fig. 2. *Corallina yenoshimensis.*

Figs. 3—4. *Corallina decussato-dichotoma.*

3. A compact form grown upon a hard substratum.
4. A loose form epiphytic on other alga.

Fig. 5. *Corallina adhærens, Lamx.*

A mass of frond epiphytic on *Digenia simplex, Holms,* with *Cor. decussate-dichotoma* mixed together.

Fig. 6. *Corallina arborescens.*

Fig. 7. *Corallina radiata*

Fig. 8. *Corallina ungulata.*

Fig. 9. *Corallina ungulata, f. brevior.*

Figs. 10—13. *Corallina officinalis. L,*

10. *α.*
11. *β.*
12. *γ.*
13. *δ.*

Figs. 14—16. *Corallina pilulifera, Post. et Rupr.*

14. *f. filiformis, Rupr.*
15. *f. Sororia, Rupr.*
16. *f. intermedia.*

Fig. 17. *Corallina squamata, Ellis et Sol.*

Fig. 18. *Corallina sessilis.*

Fig. 19. *Corallina kaifuensis.*

Fig. 20. *Corallina confusa.*

R. Uchiyama et K. Yendo Photo.

Yendo—*Corallinae verae Japonicae.*

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Revisio Umbelliferarum Japonicarum.

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With Plates I—III.

Some umbelliferous plants, possessing a strong aromatic constituent in their roots, stems and leaves, were highly appreciated in the Chinese Materia medica, and have also been well known to Japanese herbalists from remote antiquity, as is seen in some well known native works, such as Wamyōrujushō, Wamyō-honzō &c., which were written at the beginning of the ninth century.

Japanese plants were not, however, known to any Europeans, until Kaempfer who arrived in Japan in the year 1690, who described 8 species of this family of plants in his "Amoenitatum Exoticarum" (1712). Eighty-five years later, Thunberg, who also visited Japan mentioned 10 genera and 16 species of the same family in his "Flora Japonica" (1784). Still later, Siebold, in the year 1823, came to Japan and wrote his "Synopsis Plantarum Oeconomicarum" (1827), in which he mentioned only 14 species of that family. Since the publication of these pioneer works, our flora has been carefully studied by many eminent botanists, such as Zuccarini, Gray, Miquel

Maximowicz, Franchet and others. Franchet and Savatier's elaborate "Enumeratio Plantarum" appeared in the years 1875—1879, in which 24 genera and 52 species of the umbelliferae were incorporated.

At present, the total number of the species known amounts to about 40 genera and 95 species. Amongst these genera, four are restricted to northern America and Asia, viz. Cœlopleurum, Conioselinum, Osmorhiza and Phellopterus ; three, to northern Asia and European Russia, viz. Pleurospermum, Nothosmyrnium and Cenolophium.

The three genera, Cicuta, Heracleum and Ligusticum are widely distributed only in the Northern Hemisphere ; whilst one genus, Seseli, has relatively a wide distribution in the Eastern Hemisphere, not being found in North America. The remaining genera are almost cosmopolitan. Out of these 96 species, only twenty-eight are endemics ; twelve are introduced ; four, nowhere to be found in our country, must be excluded, having been erroneously recorded as Japanese by the previous botanists.

For the distribution of the species over this country and their relation to the flora of other countries, two tabular lists are given at the end of this paper.

In this paper, I have attempted to classify all the umbelliferæ which are accessible to me, from Japan, Liukiu and Formosa, describing them from the materials principally preserved in the herbarium of the Botanical Institute, Science College, Imperial University, Tokyo. The generic characters are given only in such a limited sense as are applicable to our flora, and are arranged according to Prof. Drude.*

In conclusion I desire to express my hearty thanks to Prof. J. Matsumura, at whose suggestion this investigation was undertaken, and

* Engler u. Prantl, Nat. Pflanzenfam. III. abt. VIII.

under whose constant supervision the work has been carried on. I am also indebted to Prof. K. Miyabe, of the Agricultural College, Sapporo, and to Messrs. T. Kawakami, T. Makino and many others, who have assisted me in various ways.

CONSPECTUS GENERUM.

I.—Fructus a latere valde compressus v. ad commissuram constrictus ; endocarpium e stratis cellulae elongatae vestitum ; vittae o. Umbellae simplices v. irregulariter compositae. Folia indivisa vel palmata, stipulata.

○ Mericarpia 5—costata........................Hydrocotyle.

○ Mericarpia 7—9—costata, reticulata...........Centella.

II.—Endocarpium molle ; epicarpium echinatum ; commissura lata. Folia palmatim 3-5—secta. Umbellae parvae subcorymbosae..Sanicula.

III.—Endocarpium molle ; vittae (ad valleculas interdum intrajugales) conspicuae rarissime deficientes.

○ Semen facie sulcatum v. excavatum.

◎ Fructus oblongus v. linearis, apice interdum rostratus, exalatus.

△ Fructus oblongus basi attenuatus ; juga primaria prominula ; vittae intrajugales vix conspicuae, valleculae o..................................Osmorhiza.

△ Juga prominula v. inconspicua ; fructus basi rotundatus nec attenuatus, plus minus rostratus.

□ Fructus ovato oblongus, rostrum brevius..Anthriscus.

□ Fructus longe rostratus..................*Scandix.*

◎ Fructus ovatus oblongusve a dorso subcompressus, setosus.

△ Fructus ovatus, semen facie sulcatum, juga primaria

obscura, echinata. Involucra oligophylla, petala alba... ....Torilis

△ Fructus oblongus, semen facie profunde involutum, involucrum saepe nullum. Petala alba v. rosea, setis viridibus......................................Caucalis.

◎ Fructus subglobosus glaber jugis in sicco vix prominulis ; semen stratis lignosis tectum..............*Coriandrum.*

◎ Fructus ovatus, juga plus minus elevata ; endocarpium membranaceum vittis adhærens.

△ Folia pinnatim decomposita, segmentis parvis. Fructus late ovatus, vittae inconspicuae. Carpophorum indivisum...*Conium.*

△ Involucra foliacea ; fructus oblongo-ovoideus, jugis argute elevatis, vittae ad valleculas solitariae v. 2. Carpophorum bipartitum...........Pleurospermum.

○ Semen facie planum v. convexum rarissime concavum.

◎ Juga omnia subæqualia, semen transverse semiteres.

△ Fructus a latere compressus ad commissuram constrictus, juga vix prominula (carinæ).

□ Folia integra, petala flava involuta.................... ....Bupleurum.

□ Vittae ad valleculas rarissime intrajugales v. inconspicuae, juga filiformia æqualia, petala apice inflexo-acuminata v. subplana.

* Fructus ovoideus v. late ovatus. Mericarpia glabra, vittae valleculae solitariae. Petala ovata apice acuta.

† Petala alba.

a) Calycis margo obsoletus...........Apium.

b) Calycis dentes acuti.................Cicuta.

† Petala flava.

* Fructus elongato-ovatus v. cylindricus, valleculae 1-vittatae.

† Flores paniculati. Mericarpia jugis dorsalibus 5 commissuris 2 instructa, fructus anguste oblongus......................Cryptotaenia.

† Flores umbellati......................Carum.

* Fructus ovatus basi emarginatus. Semen facie planum vel vix sulcatum. Valleculae multi-vittatae v. o.

† Vittae o, juga primaria filiformia...Ægopodium.

a) Caulis scapiformis.................Chamæle.

b) Caulis foliosus..............Euægopodium.

† Vittae ∞.

a) Involucri bractea nulla v. parva caduca. Carpophorum bipartitum......Pimpinella.

b) Involucra et involucella magna persistentia. Calycis dentes obsoleti. Fructus orbiculato-ovatus ....Nothosmyrnium.

c) Involucra et involucella ∞. Calycis lobi prominuli. Carpophorum indivisum...... ....Sium

△ Fructus globosus oblongus transverse subteres v. a dorso compressus. Juga primaria prominula v. alata. Semen transverse subteres (Seselinae).

□ Juga primaria subæqualia, exalata.

* Fructus oblongus. Juga omnia obtusissime suberosa. Carpophorum o.................Œnanthe.

* Fructus jugis filiformibus villosus.........Seseli.

□ Juga lateralia in alas augustas expansa. Folia pinnatim decomposita, laciniis linearibus.

* Juga marginalia alata, fructus a dorso valde compressus.............................*Anethum.*

* Juga marginalia vix alata.

□ Juga omnia in alas plus minus expansa.

* Semen endocarpio adhærens.

† Vittae valleculae solitariae.........Cnidium.

† Vittae valleculae 2 v. 3............Ligusticum.

* Semen nucleatum.

† Valleculae 1—vittatae...........Cenolophium.

† Valleculae 2-3-vittatae...........Cœlopleurum.

◎ Fructus a dorso valde compressus. Juga dorsalia vix elevata, lateralia in alas late expansa.

△ Fructus alae laterales membranaceae.

□ Caulis plerumque robustus. Folia ternato- v. pinnatim decomposita.....................Angelica.

□ Folia bi-tripinnata, chærophylloidea..Conioselinum.

△ Fructus etiam tota planta villosa. Juga omnia alata æqualia. Semen valde compressum......Phellopterus.

△ Fructus margo crassiusculus.

□ Folia pinnatim decomposita, laciniis linearibus. Vittae ∞ v. obscurae....................*Ferula.*

□ Juga marginalia coriacea. Vittae ad valleculas solitariae, conspicuae v. 2—3..........Peucedanum.

□ Folia pinnata. Vittae ad valleculas soliteriae, commissurae breviores.......................*Pastinaca.*

△ Fructus plano-compressus v. vix medio convexus, margine alaeformis. Vittae ad valleculas solitariae

fructu breviores. Petala radiata inæqualia..................
....Heracleum.

◎ Juga secundaria prominula primaria subæquantia.

△ Fructus glaber.....................................*Siler.*

△ Fructus setosus. Involucri bractae dissectae..............
....*Daucus.*

DESCRIPTIO SPECIERUM.

Hydrocotyle Linn.

Linn. Gen. n. 325; Willdenow, SP. Pl. p. 1360; A. Richard, Monogr. d. Gen. Hydroc. in Ann. Soc. Phys. par. IV; Koch, Gen. Trib. Pl. Umb. p. 144; De Candol, Prodr. IV. p. 59; Endlicher, Gen. Pl. II. p. 763; Benth. et Hoolk. Gen. Pl. I. p. 872; Baillon, Hist. d. Pl. VII. p. 234; Drude. in Engl. et Prantl. Nat. Pfl. Fam. theil III. abt. VIII. p. 116.

Flores bisexuales vel interdum unisexuales, calycis dentes minuti vel obsoleti, petala minuta acuta valvata, styli a basi filiformes; fructus a latere compressus, jugis primariis nerviformibus, dorsalibus prominulis, lateralibus in commissuram latentibus, secundariis inconspicuis; vittae o; carpophorum indivisum.——Herbae perennes v. annuae, prostratae ad nodos radicantes, vel rami innovanti erecti; folia palminervia v. palmatifida; stipulae parvae scariosae. Umbellae simplices plerumque capitatae vel laxe subcompositae; involucri o vel pauciphylli.

1. **H. Javanica** Thumb. Dissertatio p. 415. t. 3; A. Richard, Monogr. p. 65. no. 41; Spreng. System Veget. I. p. 877; DC. Prodr. IV. p. 67; Miquel. Fl. Ind. Batav. I. pt. 1. p. 734; Hance in Journ. Bot. XXI. p. 321; Hiern in Oliv. Fl. Trop. Afr. III p. 4; C. B. Clarke in Hook. f. Fl. Br. Ind. II. p. 667; Maxim. in

Mel. Biol. XII. p. 462 ; Forbes et Hemsl. Ind. Fl. Sin. I, in Journ. Linn. Soc. XXVIII. p. 325 ; Hemsl. et Coll. in Journ. Linn. Soc. XXVIII. p. 61 ; Henry, A. List. Pl. Formos. in Trans. Asia. Soc. Jap. vol. XXIV suppl. p. 47 ; Ito et Matsumura, Tentam. Fl. Lutch. I. p. 260 ; Diel, Fl Centr. China in Engl. Bot. Jahrb. XXIX p. 490.

H. nepalensis Hook. DC. Prodr. IV. p. 65 ; Miq. Fl. Ind. Bat. I pt. 1. p. 735. var., Miq. Cat. Mus. Lugd. Bat. Fl. Jap. p. 40 ; Miq. Prol Fl. Jap. p. 243 ; Fr. et Sav. Enum. Pl. Jap. I. p. 178.

H. polycephala Wight et Arn. Prodr. Fl. Pen. Ind. Or. I. p. 366; Wight, Illustr. Ind. Bot. I. t. 117. f. 1 ; Wight, Icon. Ind. Or. t. 1003.

H. zeylanica Dc. l.c. p. 67 ; Wight et Arn. Prodr. I. p. 366 ; Miq. Fl. Ind. Bat. I. pt. 1. p. 734.

H. hirsuta Blume. Bijdr. p. 884 ; Zolling. Syst. Verz. Ind. Arch. p. 139.

H. hirta Rubr. var. acutiloba F. Muell. in Benth. Fl. Austral. III. p. 340.

Caule repente plus minus decumbente ; foliis orbiculatis v. cordato-reniformibus 6—8 cm. vel latioribus, 7-lobatis, 7-nerviis, lobis angulatis crenatis puberulis ; pedunculis petiolo brevioribus ; umbellis dense capitatis ; fructibus parvis purpureo-punctatis.

Nom. jap. Obāchidomegusa.

Icon. jap. Honzôzufu XXXVI. fol. 1. recto. fig. med.; Sômoku-zusetsu vol. IV. fol. 63. ed. I. sub. Chidome-gusa foliis magnis ; Shitsumon-honzô Gwaihen III. t. 3.

Hab. Honshiu meridionale.—Prov. Awa: in valle humida montis Kiyosumi ; Prov. Sagami: Tôgamine in jugo Hakone (Herb. Mus. Imp.) ; Prov. Yamato: in monte Kasugayama (J. Matsumura).
Shikoku—Prov. Tosa: in pago Hônokawa (K. Watanabe, julio fl. et fr).
Kiushiu—Prov. Hizen: Nagayama in Nagasaki (Sec. Maxim) ; Prov. Chikuzen :

in monte Koshozan (Nagano); Prov. Satsuma: Shiroyama (T. Uchiyama); Ins. Tsushima: in monte Taterayama (ipse).
Liukiu—Ins. Amami—Ôshima: in Miyamauto inter Yamatohama et Taken (sec. Ito).
Formosa—Kelung (T. Makino); loco non indicato (Uyeno); Bankinsing (sec. Henry).

Distrib. China austr: Canton; India orientali; Himalaya Khasia, Malabar, Ceylon, Decan; Malaya; Java; Phillippinæ; Australia; Nova Zelandia; Africa.

In speciminibus ex Formosa folia minora, lobi margo obsoletus nec angulatus, iis nepalensibus similibus videtur; stipulae parvae membranaceae; fructus rite orbiculatus.

2. **H. conferta** Wight. Icon. Ind. Orient. t. 1002; C. B. Clarke in Hook. f. Fl. Br. Ind. II. p. 668.

Herba decumbens setulosa v. pubescens; foliis reniformibus v. cordatis orbiculatis obsolete 7-9-lobulatis, 7-9-nerviis, crenatis subintegrisve; ramis axillaribus; petiolis brevibus pubescentibus; stipulis subtriangulatis coriaceis; umbellis multifloris oblongo-capitatis subsessilibus; fructibus orbiculatis parvis.

Hab. Formosa: a Dikui usque Tsuibolin (C. Owatari. Janualio fl. et fr.)

Distr. India orientali: Nilagiri.

Folia 3 cm. diam. forma et magnitudine valde variabilia rigidula basi subcordata v. subacuta; umbellae ad nodum ortae. Antecedenti valde affinis, differt umbellis sessilibus.

3. **H. rotundifolia** Roxb. Fl. Ind. II. p. 668; DC. Prodr. IV. p. 64; Wight, Illustr. Ind. Bat. t. 564 et Ic. Pl. Ind. Orient. t. 564; Benth. Fl. Hongkong. p. 134; C.B. Clarke in Fl. Br. Ind. II. p. 668; Maxim. in Mel. biol. XII. p. 461; Forbes et Hemsl. Ind. Fl. Sin. I. p. 825; Henry, List. Pl. Form. in Tr. Asia Soc. Jap. XXIV Suppl. p. 47; Ito et Matsumura, Tentam. Fl. Lutch. sect. I. p. 259; Diel. in Engl. Bot. Jahrb. XXIX p. 491.

H. nitidula A Richard, Monogr. p. 60, no. 35, fig. 33 ; Spreng. Syst. Veget. 1. p. 877 ; DC. l.c. p. 66 ; Zoll. Syst. Verz. Ind. Archip. p. 139 ; Hiern in Oliver, Fl. Tr. Afr. III. p. 5 ; Miq. Prol. p. 243.

H. Sibthorpioides Lam. Encycl. III. p. 153 ; Spr. Syst. Veg. 1.p. 877 ; DC. l.c. p. 66 ; Fr. et Sav. Enum. Pl. Jap. I. p. 178.

H. puncticulata Miq. Fl. Ind. Batav. I. pt. 1. p. 733.

H. Zollingeri Molkenb. Miq. Fl. Ind. Batav. I. pt. 1. p. 733 ; Zoll. Syst. Verz. p. 139.

H. tenella Don. in DC. l.c. p. 64 ; Wight et Arn, Prodr. I. p. 366.

H. glabrata Black. (sec. Miq.)

H. batrachium Hance in Ann. Sc. Nat. 4^{me} Ser. XVIII. p. 220. Caule repente, foliis orbiculato-cordatis v. reniformibus basi profunde fissis, glabris nitidulis v. pubescentibus, 5-7-nerviis, 5-7-lobatis, lobis tridentatis, circa 1/2-1 cm. diam.; petiolis gracilibus, 1-3 cm. longis, pedunculis subæqualibus, stipulis membranaceis ; umbellis 3—15—floris, floribus minutis subsessilibus, involucri phyllis paucis ; fructibus orbiculatis compressis interdum puncticulatis.

Nom. jap. Chidomegusa.

Icon. jap. Honzōzufu XXXVII. fol. 1. recto. fig. super et inf.

Hab. In variis locis : humidis sylvaticis, macribus fere ubique.

Prov. Rikuzen: Iwakiri (Herb. Makino); Prov. Iwashiro: circa Oppidum Fukushima (K. Nemoto); Prov. Musashi: Circa urbem Tokyo (Ipse! a Majo usque in Octobrem fl. et fr.); Prov. Sagami: in jugo Hakone (forma nitidula!), Yokoska (Savatier! sec. Franch.), Yokohama (sec. Maxim.); Prov. Suruga: ad pedem montis Fuji (J. Matsumura); Prov. Ise: in oppidulum Yokkaichi (K. Tani); Prov. Izumi: Yamada (S. Matsuda).

Shikoku—Prov. Tosa: Sakawa (T. Makino).

Kiushiu—Prov. Hizen: Nagasaki (Oldham); ins. Tsushima (ipse). Liukiu—Insula Okinawa, ad Shuri (T. Ito ex Tentam.), inter Nafa et Tchatan (sec. Ito); in ins. Miyako circa Gushiku (Tatitu!); loco non indicato (Benth. et Wright!)

Formosa—Taipe in regione boreali (C. Owatari); Pekoh (T. Makino); Manga

(T. Makino); Kelung (T. Makino; jurisdictione Taitoo, in pratis Pinang (Y. Tashiro); Byolitsu (Honda); loco non indicato (Uyeno); Takaw (sec. Henry).

Distrib. China australi: Kiangsu, Kiangsi, Hupeh, Kwangtung, Hanchow (C. Owatari, junio 1897); Himalaya, Bengal, Malabar, Zeylonia, Malaya, Australia, Africa.

Adnot. In speciminibus omnibus in Formosa lectis: caule repente terete filiforme, foliis longe petiolatis supra glabris subtus pilosulis profunde tripartitis; lobis cuneatis, inciso-dentatis, lobis lateralibus bifidis, petiolis gracilibus, apice puberulis, stipulis membranaceis obcordatis; umbellis dense capitatis 7-floris; pedunculis petiolo brevioribus; fructibus orbiculatis jugis lateralibus conspicuis. Species in generali H. tripartitae (Rich. Monogr. no. 46. fig. 25) arcte similis.

Var. pauciflora m. Caule repente, foliis glabris nitidulis reniformibus 5-7-lobis, 5-nerviis, lobis 3-dentatis, basi latissime sinuatis, 5-6 mm. latis, stipulis ovatis parvis, petiolis peduculis longioribus vel subæqualibus; umbellis 3- rarissime 4—floris; involucris 3-4-phyllis setaceis, fructibus orbiculatis 5-jugis, jugis lævibus.

Hab. Prov. Musashi: in umbrosis humidis, circa urbem Tokyo.

Saepe cum typo crescens. A Junio ad Octobrem fl. et fr.

4. **H. Wilfordi** Maxim. in Mel. biol. XII p. 463; Forbes et Hemsl. Ind. Fl. Sin. I p. 326; Palibin, Consp. Fl. Kor. I. p. 96.

Caule prostrato ramis innovantibus erectis, foliis orbiculatis v. reniformi-cordatis circa 8 cm. diam. obsolete 7—lobis, lobis 3—crenatis ad nervos setosis; petiolis 3—10 cm. longis apice puberulis; stipulis rotundatis membranaceis; pedunculis 18—40 mm. longis; umbellis multifloris, floribus brevi pedicellatis dense capitatis (pedicellis ½—1

mm. longis), petalis viridescentibus triangularibus staminibus petalis æquilongis antheris flavis demum brunneis, fructibus orbiculatis compressis utrinque costatis 1.5-1 mm. longis.

Nom. jap. *No chidome.*

Hab. Ins. Hokkaidō—Prov. Oshima: Hakodate (Miyabe et Tokubuchi); Prov. Iburi: Oshamanbe (Herb. Kawakami.) Augusto.
In Honshiu boreali Prov. Mutsu: in agris Tokiwano prope Aomori; Prov. Iwashiro: in tractu Aizu, circa pagum Moniwa (Herb. Makino); Prov. Shinano: in monte Wadatoge (ipse), in monte Shimizutôge (Makino); ins. Sado: in monte Kimpokusan (S. Okubo); Prov. Musashi: in pratis circa urbem Tokyo (Majo fl!); Prov. Sagami: Yokohama (sec. Maxim, Uraga (ipse); Prov. Izu: Yoshida; Prov. Ise: prope Yokkaichi (K. Tani); Prov. Ōmi: in monte Ibukiyama; Prov. Izumi: Asaka (S. Matsuda); Prov. Harima; ad pagum Kajimamura (U. Ôgami).
Kiushiu—Prov. Buzen: in monte Iwatake (Matsumura et Yatabe); Prov. Bungo: Ôita (A. Ideta); Prov. Chikuzen: Ôkawa mura (K. Nagano); Prov. Higo: Kumamoto (S. Satō ex herb. Kawakami et ipse); ins. Tsushima (ipse).

Distrib. Korea.

5. **H. ramiflora** Maxim. in Mel. biol. XII. p. 463.

Caule glabro gracili subascendenti; foliis orbiculatis oblongis quasi peltatis v. rarius reniformibus crenulatis; stipulis ovatis; pedunculis petiolis longioribus, umbellis capitatis multifloris, pedicellis brevibus; fructibus valde compressis orbiculatis utrinque costatis.

Hab. Hokkaidō—Prov. Shiribeshi: Zenibako (J. Matsumura); Prov. Oshima; Hakodate (sec. Maxim).
Honshiu—Prov. Iwashiro: in pago Moniwa (Herb Makino); Prov. Echigo: Sasaguchi (K. Yendō); Prov. Musashi: circa Tokyo (T. Makino et ipse Kanagawa (T. Makino); Prov. Shimotsuke: Nikkō.

Omnibus partibus antecedenti similis, differt foliis subpeltatis atroviridibus glabris.

Centella L.

Linn. Gen. n 1051; Urban in Marti, Fl. Brasil, vol. XI.

fasic. 1" ; Drude in Nat. Pfl. fam. III abt. VIII. p. 119. Hydrocotyle (subgen, Centella) in DC. Prodr. IV. p. 88 ; Richard. Monougr. p. 40 ; Endl. Gen. Pl. p. 763 ; Benth. et Hook. Gen. Pl. I. p. 873 ; Baillon, Hist. d. Pl. VII. p. 139.

Flores omnes perfecti, calycis dentes minuti ; petala ovata imbricata ; fructus a latere compressus, ad commissuram latior ; mericarpia glabra v. hirta 7-9-costata reticulata—Herba repens ; folia orbiculato-reniformia integerrima interdum incisa ; umbellae plerumque triflorae, involucri 2-bracteati.

1. **Centella asiatica** Urb. in "Marti. Fl. Brasil. vol. XI. fasc. 1" (1879) ; Drude in Nat. Pfl. Fam. III abt. VIII. p. 119 ; Britton et Brown, Illustr. Fl. North. St. &. Can. II. p. 541 ; Diel. in Engl. Bot. Jahrb. XXIX p. 491.

Hydrocotyle asiatica L. Sp. 234 ; Willd. Sp. Pl. p. 1362 ; Thunb. Fl. Jap. p. 116 ; Aiton, Hort. Kew II. p. 118 ; A. Richard, Monogr. p. 40 no. 15 fig. 11 ; Roxb. Fl. Ind. II. p. 88 ; Spr. Syst. Veg. I. p. 875 ; DC. Prodr IV p. 62 ; Wight et Arnot. Prodr. Fl. Pen. Ind. I. p. 366. no. 1130 ; Wight, Illustr. Ind. Bot. t. 565 ; Wight, Ic. Pl. Ind. Or. t. 565 ; Hook. et Arnot. Bot. Beech. Voy. p. 26 ; Seeman, Fl. Vitiens. p. 113 ; Benth. Fl. Hongkong. p. 134 ; Muell. Fragm. Phytogr. Austr. VII. p. 147 ; Benth. Fl. Austr. III. p. 346 ; Miq. Prol. Fl. Jap. p. 243 ; Fr. et Sav. Enum. Pl. Jap. I. p. 178 ; Harvey et Sonder, Fl. Cap. II. p. 527 ; W. P. Hiern in Fl. Br. W. Ind. p. 307 ; Hemsl. in Rep. Voy. Challeng. bot. Atl. Isl. p. 35 ; C. B. Clarke in Hook. f. Fl. Br. Ind. II. p. 669 ; Maxim. Mel. Biol. XII p. 461 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 324 ; Coult. et Rose Rev. N. Am. umb. p. 136 ; Hemsl. et Coll. in Journ. Linn. Soc. XVIII. p. 61 ; F. Reinecke, Fl. d. Samoa ins. in Engl. Bot. Jahrb. XXV. p. 663 ;

Trimen Handb. Fl. Ceyl. II. p. 276 ; Henry in Tr. Asia Soc. Jap. XXIV. suppl. p. 47 ; Ito et Matsumura, Tentam. Fl. Lutch. I. p. 257.

Hydrocotyle nummularioides A. Richard, Monogr. p. 36, no. 11, fig. 9 ; Spr. Syst. Veg. I. p. 875 ; DC. Prodr. IV. p. 63.

H. asiatica L. var. hebecarpa Hassk. Pl. Jav. Rar. p. 459 ; Zoll. Syst. Verz. Ind. Archip. p. 138.

H. hebecarpa et *inæqualis* DC. l.c. p. 63.

H. cordifolia Hook. f. in Hook. Ic. Pl. IV. p. 303.

H. dentata A. Richard, Monogr. p. 42, no. 16, fig. 22.

H. ficarioides Lamk. Encycl. III. p. 153 ; Rich. l.c. p. 37, no. 12, fig. 12.

H. abbreviata A. Richard, l.c. p. 43, no. 17, fig. 19 ; DC. l.c. p. 63.

H. repanda Pers. Spr. Syst. Veg. I. p. 875 ; Chapm. Fl. S.U. St. p. 159.

H. lunata Lamk. l.c. III p. 152.

H. brevipes, pallida et *β. integra* DC. l.c. p. 63.

Trisanthus cochinchinensis Lour. Fl. Cochinch. ed. Willd. p. 219.

Herba perennis glabra v. villosula, caule prostrato, foliis pedunculisque ad nodos fasciculatis ; foliis orbiculatis reniformibus 5-7-rarius 9-nerviis, nervis elevatis subdichotomis reticulatis, 2-6 cm. diam. æqualiter crenatis vel sub-integris ; petiolis 5-20 cm. longis basi plus minus vaginantibus ; pedunculis brevibus, petiolis pedunculisque juvenilibus puberulis ; umbellis 3-rarius 4-floris, stylis brevibus ; involucris 2 ovatis glabris v. puberulis ; fructibus a latere compressis orbiculatis 3 mm. latis, carpellis oblongis reticulato-costatis, epicarpiis crustaceis, extus spongiosis, intus membranaceis e cellulis tenuissimis constitutis, endocarpiis osseis.

Nom. Jap. Tsubo-kusa ; *Bumbudō* (Nom. Liukiu.) ; *Hamkatkätsan*

蛄殼仔草 (Nom. Formos. sec. C. Owatari et Uyeno).

Icon. Jap. Honzōzufu XXXVII, fol. 1. verso.

Hab. in Japonia australi, plerumque in arenosis maritimis.

Honshiu.—Prov. Hitachi: in radice montis Tsukuba (fide Makino); Prov: Shimosa: Mama et Abiko non procul a Tokyo (ipse); Prov. Sagami Yokohama et Yokoska (Maxim), Uraga (ipse, Julio et Octobri fl. et fr.); Prov. Suruga: Omiya; Prov. Mino (K. Nagano): Prov. Izumi: Chino-oka (S. Matsuda).

Ins. Shikoku—Prov. Tosa (T. Makino).

Kiushiu—Prov. Hizen: Nagasaki (Maxim); Prov. Chikuzen: Hachiman-mura (K. Nagano); Prov. Satsuma: Shiroyama; Prov. Hiuga: Tsuno (Herb. Mus. Imp); Prov. Higo: Sunatori prope Kumamoto (ipse): Ins. Tsushima (ipse).

Ins. Bonin (Hook. et Arn. Herb. Makino et Yatabe).

Liukiu.—Ins. Okinawa: in oppido Nafa ad Izunzaki (Yamada); circa Tumigushiku (sec T. Ito). prope Shuri (K. Miyake); archip. Yayeyama, ins. Kurushima (H. Kuroiwa).

Formosa—Kelung (T. Makino); ins. Sharyô (T. Makino); Lengaliau, in Formosa australi (C. Owatari); Kōshun (C. Owatari); loco non commemorato (Uyeno. No. 8).

Distr. In regionibus temperatis tropicisque late dispersa. China: Kwantung, Hongkong; India orientali: Bengalia, Himalaya, Nilagiri, Zeylonia; Fiji; Java; Nova-zealandia; Australia; Africa australi; America boreali et australi; Insulis indiis occidentalibus.

var. crispata Maxim. in Mel. Biol. XII p. 461; Forbes et Hemsl. Ind. Fl. Sin. I. p. 324; Bretschneider, Hist. Europ. Bot. Disc. Chin. p. 367.

H. lurida Hance in Walp. Ann. II. 690 (teste Hemsl.)

Foliorum marginibus crispatis, valde inæqualiter inciso-dentatis.

Nom. Jap. Chijimi-tsubokusa.

Hab. in hortis japonensibus tantum culta.

Distr.. Hongkong.

Sanicula (Tourn) L.

Linn. Gen. n. 326; Hoffm, Umb. p. 65; DC. Prodr. IV. p. 84; Endl. Gen. Pl. p. 767; Benth. et Hook. Gen. Pl. 1. p. 880; Baillon, Hist. d. Pl. VII. p. 241; Drude in Engl. et Prantl. Nat. Pfl. Fam. III. abt. VIII. p. 137.

Flores plerumque unisexuales in umbellula saepe intermixti; calycis dentes prominuli acuti persistentes; petala alba ob costam superne intrusam emarginata leviter imbricata; fructus ovoideus v. orbiculatus echinatus a latere leviter compressus; commissura lata; juga vix conspicua, vittae parvae intrajugales, in endocarpio irregulariter sparsae; carpella subteretia; carpophorum o; semen transverse subteres facie planum——Herba erecta; folia palmatim 3-7-partita, segmentis dentatis v. lobatis caulina pauca; umbellae irregulariter compositae pauci-radiatae.

1. **Sanicula europæa** L. Sp. Pl. 339; Willd. Sp. Pl. p. 1366; Aiton, Hort. Kew. II p. 119; Sow. Engl. Bot. t. 98; DC. Prodr. IV. p. 84; C. B. Clarke in Hook. f. Fl. Br. Ind. II. p. 670; Hiern in Oliv. Fl. Trop. Afr. III. p. 6; Sond. in Fl. Cap. II p. 533; Hemsl. et Forb. Ind. Fl. Sin. p. 326; Diel in Engl. Bot. Jahrb. XXIX. p. 491.

S. *elata* Hamilt. in Don. Prodr. Nep. 183; DC. l.c.p. 85; Wight et Arnot, Prodr. Fl. Pen. Ind. Or. 1. p. 361; Wight, Ic. Pl. Ind. t. 334 et 1004; Ill. Pl. Ind. Or. t. 117, fig. 2; Miq. Prol. Fl. Jap. p. 244; Fr. et Sav. Enum. Pl. I. p. 178; Franch. Pl. David. p. 137 (var. acaulis.)

S. *canadensis* Thunb Fl. Jap. p. 116.

S. *chinensis* Bunge. Enum. Pl. Chin. Bor. p. 32; Hance in

Journ. Bot. 1874. p. 260 ; Maxim. Ind. Fl. Pek. in Prim. Fl. Am. p. 472 ; Palibin, Consp. Fl. Kor. I. p.

S. *montanum* Reinw. DC. l.c.p. 85.

S. *javanica* Blume Bijid. p. 882 ; DC. l.c. p. 85.

Herba perennis glabra, caule erecto sulcato simplici 2-3 pedali ; foliis radicalibus longe petiolatis 5-lobis 3-8-cm. diam., caulinis superioribus brevi petiolatis 3-partitis ; segmentis omnibus obovatis apice tri-partitis basi cuneatis argute serratis saepe duplicato—serratis, petiolis glabris canaliculatis basi plus minus amplexicaulibus 15—20 cm. longis ; umbellis irregulariter compositis ; involucris foliaceis lobatis ; floribus fertilibus umbellularum 3 sessilibus, masculis brevi pedicellatis ; calycis lobis lineari-lanceolatis echinatis, petalis albis involutis, stylis nunc elongatis nunc brevibus ; involucelli phyllis linearibus fructibus brevioribus ; fructibus 4—5 mm. longis, a latere leviter compressis ovoideis.

Nom. Jap. Umano-mitsuba, Yama-mitsuba.

Icon. Jap. Somoku-zusetsu V. fol. 31.

Hab. per totam Japoniam, communissimis.

Hokkaidō (Yezo)—Hakodate (Yatabe); Prov. Ishikari: Sapporo (Kawakami) Poronai (Kawakami), Sorachibuto (Kawakami); Prov. Iburi: Oshamanbe (Kawakami) ; Prov. Kitami, Ins. Rishiri (Herb. Kawakami).

Honshiu—Prov. Rikuzen: in monte Kattadake (Ipse); Prov. Iwashiro (K. Nemoto); Prov. Shimotsuke: in alpibus Nikkō; Prov. Shinano: in radice ignivomi Asama (ipse); Prov. Musashi; circa Tokyo (Julio fl. Junio—Augustio fr. mat!); Prov. Sagami: Misaki et Hiratsuka; Prov. Suruga: in monte Fuzi (N. Ohno); Prov. Ise (Tani); Prov. Yamato (Herb. Mus. Imp.); Prov. Harima (U. Ogami.)

Kiushiu—Ins. Tsushima (ipse).

Distr. China : Peking, Jehol, Kiukiang, Hupeh ; Korea ; India : Himalaya, Khasia, Burma, Malabar, Zeylonia ; Europa ; Africa.

2. **S. satsumana** Maxim. in Mel. biol. XII. p, 465 ;

Matsum. in Tokyo Bot. Mag, XII. p. 3 ; Itō et Matsumura, Tentam. Fl. Lutch. sect. I. p. 528.

Caule erecto 1/2 pedali sub-aphyllo, foliis radicalibus longe-petiolatis circumscriptione pentagonis tripartitis, segmentis 2-3 lobatis rhomboideis basi cuneatis crenatis mucronatis margine albolameligeris ; petioli 1/3 pedalibus glabris basi dilatatis ; involucris foliolis paucis setaceis v. subfoliaceis pinnatis ; umbellis compositis 5—7 radiatis ; involucellis 3—6 phyllis setaceo-dentatis ; umbellulis 5—6 floris, floribus exterioribus masculis longe pedicellatis, centralibus unifloris fertilibus, calycis dentibus prominulis setaceis, petalis albis obovatis apice emarginatis ; filamentis petalis duplo longioribus, stylis erectis demum reflexis ; fructibus ovatis echinatis 2—1½ mm. longis.

Nom. Jap. Hime-umanomitsuba (sec. J. Matsumura).

Hab. Kiusiu : Prov. Satsuma, Kagoshima (sec. Maxim) ; Liukiu : Ins. Okinawa, secus rivulos prope Yakabi (J. Matsumura. Majo anno 1897. fr.)

Anthriscus Hoffm.

Hoffm. Umbellif. p. 38 ; DC. Prodr. IV. p. 222 ; Benth, et Hook. Gen Pl. I. p. 899 ; Endl. Gen. Pl. II. p. 786 ; Baillon, Hist. d. Pl. VII. p. 232 ; Drude in Nat. Pfl. Fam. theil. III abt. VIII p. 152.

Calycis lobi minuti ; petala oblonga v. cuneata emarginata cum lacinula inflexa v. obtusa ; stylopodia parva conica ; fructus ovato-oblongus v. cylindricus a latere compressus, jugis primariis sursum conspicuis, deorsum inconspicuis vel leviter muriculatis ; vittae vix conspicuae ad valleculas solitariae v. extrajugales ; semen facie profunde sulcatum.—Herbae annuae v. perennes ; folia pinnatim-decomposita ; umbella composita, involucra 1—2 phylla v. nulla ; flores albi.

1. **Anthriscus sylvestris** Hoffm. umbellif. p. 40 et 46. t. 1. f. 19; DC. Prodr. IV. p. 223; Ledeb. Fl. Ross. II p. 346; A. Gray, Bot. Jap. p. 390; Miq. Prol. Fl. Jap. p. 252; Hiern in Oliv. Fl. Trop. Afr. III. p. 16; Fr. et Sav. Enum. Pl. Jap. I p. 183; Forbes et Hemsl. Ind. Fl. Sin. I. p. 330; K. Miyabe, Fl. Kurile isl. (Mem. Bost. Soc. Nat. Hist. IV. n. VII) p. 235: Diel. Fl. Cent. China in Engl. Bot. Jahrb. XXIX p. 492.

Anthriscus nemorosa Fr. Schm (non Spr.) Fl. Sach. p. 140.

Chærophyllum sylvestri L. Sp. 368; Spr. Syst. Veget. I. p. 903; Sow. Engl. Bot. t. 752.

Chaerophyllum seminibus nitidis scabris....................Gmel. Fl. Sibir. I. p, 210, no 26. t. 49.

Caule 2—3 pedali glabro sulcato ramoso; foliis circumscriptione deltoideis inferioribus 30 cm. longis bipinnatis, segmentis oblongis v. lanceolato-oblongis pinnatifidis, subtus pilosis lacinulis oblongis; petiolis basi dilatatis attenuatis amplectentibus; vaginis membranaceis margine hirsutis; involucro nullo; umbellis 6—8 radiatis, radiis circa 2—5-cm. longis; involucelli phyllis 4—5 ovato-lanceolatis acuminatis membranaceis villosulis reflexis; umbellulis 6—7 aut multifloris, aliis fecundis aliis sterilibus, floribus exterioribus interioribus majoribus; petalis albis inæqualibus radiatis exterioribus maximis, obovatis apice leviter emarginatis, staminibus brevibus antheris albis; fructibus oblongis ad basin versus apicem pedicellorum attenuatis, vittis indistinctis, seminibus facie concavis.

Nom. Jap. Shaku, Kojaku, Ichari-kina (Nom. Aino).

Icon. Jap. Honzôzufu vol. 47. fol. 9 et 10; Sômôkuzusetsu v. fol. 9.

Hab. per totam Japaniam. Kurile—Furubetsu et Shana in ins. Etorop (Sec. Miyabe); Tokotan in Ins. Urupp (K. Jimbō);
Hokkaido (Yezo)—Prov. Iburi: Izari prope Chitose (Julio. fl); Prov. Ishikari: circa Sapporo (Yatabe, Kawakami).

Honshiu—Prov. Rikuzen: Sendai (T. Ichimura); Prov. Shinano: in monte Togakushi Julio fl.); Prov. Musaski: prope Tokyo (sec Siebold); circa oppidulum Ōme (ipse. Maio 1900 fl.), Prov. Harima in pagum Kashimamura (U. Ōgami).
Kiushiu—Prov. Chikuzen: Ad ripas fluvii Taragawa, Kasuyagôri (K. Naflano).

Distr. China boreali, Sibiria ural., Rossia arctica, Africa boreali, Europa.

2. **A. cerefolium** Hoffm. umbellif. p. 41. t 1. f. 21.
Introductum? Savatier no. 505!

Scandix L.

Scandix pecten-veneris L. Nuperrime introducta!

Osmorhiza Rafin.

DC. Prodr. IV. p. 232; Endl. Gen. Pl. II. p, 789; Benth. et Hook. I. p. 897; Baillon Hist. d. Pl. VII, p. 233; Drude in Nat. Pfl. Fam. theil III. abt. VIII. p. 153.
Washingtonia, Rafin, "Am. Month. Mag. 2": 176; Britton et Brown, Ill. Fl. North. St. a. Canad. II. p. 530.

Calycis limbus obsoletus; petala obovata leviter emarginata inflexa; fructus elongato-cylindricus a latere compressus basi ad pedicellum attenuatus; mericarpia angulata, jugis 5 acutis hispidulis, valleculis evittatis, commissuris sulcatis, carpophoro 2—fido; semen teres—Herba perennis pubescens; folia biternata v. ternato-pinnatisecta foliolis obovatis vel ellipticis; umbella pauciradiata; flores centrales masculi, exteriores fertiles.

1. **Osmorhiza japonica** S. et Z. Fl. Jap. Fam. Nat. n. 431; Fr. et Sav. Enum. Pl. Jap. I p. 185; Maximowicz Mel. Biol, XII. P. 46.

O. longistylis A. Gray. Bot. Jap. p. 391 ; Miq. Prol. Fl. Jap. p. 252.

Chærophyllum aristatum Thunb. Fl. Jap. p. 119.

Herba perennis rhizomate crasso ; caule tereti puberulo 1-2 pedes alto ; foliis radicalibus longe petiolatis trisectis, segmentis bipinnatisectis partitisve, laciniis oblongis ellipticis vel obovatis inciso-dentatis ad nervos pubescentibus, vaginis amplis dilatatis margine membranaceis ; involucris oligophyllis (2-4) inæqualibus ovato-lanceolatis caducis ; umbellis 3-5 radiatis ; involucelli foliolis 5-6 ovato-lanceolatis villosis subæqualibus erectis dein reflexis ; umbellulis plurifloris; floribus masculis brevi pedicellatis, staminibus petalis longioribus, antheris albis petalis oblongis a medio leviter constrictis, stylis rudimentariis instructis ; floribus fertilibus longe pedicellatis, stylis erectis petalis subæqualibus stylopodio conico; floribus masculis præcocioribus ; fructibus elongato-linearibus mericarpiis setaceis ; carpophoris bifidis ; pedunculis 6 cm., pedicellis 1½ cm. longis ; fructibus 2 cm. × 2 mm.

Nom. Jap. Yabuninjin, Nagajirami.

Icon. Jap. Sômoku-zusetsu vol. V. fol. 7.

Hab. Hokkaidô (Yezo)—Prov. Ishikari : in monte Moiwa (J. Matsumura fr) ; circa urbem Sapporo ; Prov. Iburi : Shizukari (Herb. Kawakami).
Honshiu—Prov. Rikuzen : in monte Taihakuzan circa Sendai (Herb. Yasuda Maio fl.) ; Prov. Uzen : Hondōji (julio 1887) ; Prov. Iwashiro : in monte Nakayama-tōge (K. Nemoto) ; Prov. Musashi : in Tokyo vulgare (Aprili fl. Junio fr. mat.), in monte Takao (ipse) ; Prov. Shinano : in radice montis Komagatake (Augusto 1880) ; in pedes montis Asama (ipse) ; Prov. Izu : in monte Amagi ; Okada in ins. Ōshima (S. Okubo) ; Prov. Kaga : in alpibus Hakusan (Yatabe).
Kiushiu—Ins. Tsusima : Izuhara (ipse).

Torilis Adans.

"Adans. Fam. d. Pl. II. p. 99" ; Hoffm. Umb. 49 t. 1. f. 8 ; Spr. Syst. Veg. I. p. 898 ; DC. Prodr. IV. p. 218 ;

Endl. Gen. Pl. II. p. 786 ; Drude in Nat. Pfl. Fam. theil III. abt. VIII. p. 155.

Caucalis Benth et Hook Gen. Pl. I. p. 928 (partim).

Calycis lobus triangulari-lanceolatus persistens ; petala obovata cum lacinula inflexa ; fructus ad commissuram constrictus ovatus, stylis brevibus reflectis ; juga primaria setulosa ; vittae valleculae solitariae (tota vallecula setis tecta), commissura bivittata ; semen facie profunde sulcatum——Herba annua ; folia bipinnatisecta hispidula ; umbellae 6-10-radiatae ; involucrum et involucellum oligophylli lanceolati ; flores albi.

1. **Torilis Anthriscus** Bernh. "Syst. Verz. Erf. p. 167" 1806.

Torilis anthriscus Gmel. "Fl. Bad 1. p. 615" ; Spr. Syst. Veget I. p. 898, DC. Prodr. IV. p. 214 ; Ledeb. Fl. Ross. II. p. 345 ; Wight et Arn. Prodr. Fl. Pen. Ind. Or. I. p. 374 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 337 ; Henry. List Pl. Form. p. 47 ; Palibin ; Consp. Fl. Kor. I. p. 98 ; Diel. Fl. Cent. China in Engl. Bot. Jahrb. XXIX p. 492.

Caucalis anthriscus Scop. C. B. Clarke in Hook f. Fl. Br. Ind. II. p. 718 ; Sow. Eng. Bot. t. 987 : Coult. et Rose, Rev. N. Am. Umb. p. 33 ; T. Itô et J. Matsumura, Tentam. Fl. Lutch. sect. 1. p. 532.

Caucalis japonica Houth. Nat. Hist. XXVI p. 42 Fig. 1. A (1777) ; Spr. Syst. Veg. I. 896 ; Fr. et Sav. Enum. Pl. Jap. I. p. 190 ; T, Makino, Bot. Mag. Tokyo VII p. 44.

Caucalis orientalis Lour. Fl. Cochinch. ed Willd. p. 221.

Torilis elata. Spr. DC. l.c. p. 220.

Torilis japonica DC. l.c. p. 219 ; Hook. et Arn. Bot. Beech. Voy. p. 189 et 264 ; A. Gray. Pl. Coll. Perry Exp. p. 312 ; Franch. Pl. David. I. p, 145.

Tordylium anthriscus. L. Sp. Pl. 346.

Caule erecto puberulo striato; foliis bipinnatisectis, segmentis oblongo-cuneatis pinnatifidis pubescentibus, laciniis integris aut 1-2-dentatis; petiolis basi dilatatis; umbellis 6-7-radiatis, involucris involucellisque oligophyllis linearibus puberulis, umbellulis paucifloris; calycis dentibus setuloso-scabris, petalis albis obovatis acumine inflexis dorso setulosis; fructibus ovatis $1\frac{1}{2}$ mm. longis, setis rigidis apice uncinatis, seminibus facie planis v. subconvexis.

Nom. Jap. *Yabujirami.*

Icon. Jap. Somoku-zusetsu V. fol. 5.

Hab. in graminosis totius Japoniae frequens. Junio—Julio fl. et fr.

Hokkaidō (Yezo)—Prov. Iburi: Muroran (J. Matsumura), Oshamambe (Herb. Kawakami); Chitose; Prov. Ishikari: Sapporo (Herb. Kawakami); Prov. Kitami: Abashiri (Kawakami).

Honsiu—Prov. Mutsu: In pratis Tokiwano in tractu Tsugaru; Prov. Uzen: Hondoji (Matsumara et Yatabe); Prov. Rikuzen: Aone (ipse); Prov. Iwashiro: circa urbem Fukushima (K. Nemoto); Prov. Shimotsuke: in monte Nikkō; Prov. Shinano: in monte Asama (ipse) et in monte Omine (Matsumura); Prov. Musashi: Tokyo in pratis vulgare; Prov. Sagami: Uraga (ipse); Prov. Suruga: in ignivomo Fuji (N. Ôno); Prov. Ise: Sakakibara; (K. Tani); Prov. Omi: in monte Ibukiyama; Prov. Izumi: Sakai (S. Matsuda).

Shikoku—Prov. Awa: Mitsumura, Wakimachi et Nishiu (Yatabe); Prov. Tosa: in monte Tsuetate (Yatabe), ad ripas aquarum Mononobe (S. Yano), in pago Ochimura (T. Makino).

Kiusiu—Prov. Satsuma: Shiroyama; Prov. Higo: Kumamoto (S. Satō in Herb. Kawakami); Prov. Chikuzen: Hakozaki (K. Nagano); Prov. Tsushima (ipse).

Liukiu—Ins Amami-Oshima: ad Naze (sec. T. Itô); Ins. Miyako (Tashiro); circa Gushiku (Tatitu, sec. Itô).

Formosa—loco non indicato (Uyeno 8. Martio 1898. fl).

Distr. Europa, China, Korea, Siberia, India orientali, Africa boreali.

Caucalis L.

Linn. Gen. n. 331; Hoffm. Umb. p. 54; DC. Prodr. IV. p.

216 ; Endl. Gen. Pl. p. 786 ; Benth et Hook. Gen. Pl. I. p. 928 ; Drude in Nat. Pfl. Fam. Theil. III abt. VIII. p. 157.

Calycis limbus 5 ovato-lanceolatus v. minutus. petala obovata cum lacinula inflexa radianta ; stylopodium parvum ; fructus a latere vix compressus, juga primaria setosa ; valleculae 1-3 seriatim echinatae ; vittae ad valleculas solitariae ; semen facie valde involutum ——Herba annua hispida ; folia pinnatim decomposita ; umbellae pauciradiatae (2-6). pedicellus brevis, involucrum et involucellum o. vel oligophylli.

1. **Caucalis scabra** Makino. Caule erecto ramoso tereti piloso viridi 1-2 pedali, ramis axillaribus ; foliis tripinnatisectis, segmentis primariis ovatis, ultimis oblongis acutis subpinnatifidis pubescentibus, laciniis tenuibus oblongo-lanceolatis ; petiolis basi dilatatis margine membranaceis ; involucro nullo vel 1-2-phyllo ; umbellis 3 radiatis oppositifoliis, pedunculis 2-3-vel multi-cm. longis, involucellis oligophyllis linearibus scabriusculis inæqualibus pedicellis brevioribus, umbellulis multifloris, calycis dentibus minutis, petalis roseis obovatis orbiculatisve apice inflexo-acuminatis dorso parce setulosis; stylopodio planiusculo, stylis brevibus; fructibus oblongis 5 mm. longis pedicellis duplo longioribus, setis rigidis apice uncinatis carpophoris indivisis. valleculis univittatis ; seminibus subteretibus, facie involutis.

Caucalis scabra Makino in Bot. Mag. Tokyo Bd. VII p. 14 (Jap.)

Torilis scabra DC. Prodr. IV. p. 216 ; Miq. Prol. Fl. Jap. p. 252 ; Zoll. Syst. Verz. p. 139?

Torilis praetermissa (Hance) Franch. in Pl. David. p. 145?

Caucalis praetermissa Hance in Ann. Sc. Nat. Ser. V. t. v. p. 244? Franch. Stirp. Nov. Rar. Fl. Jap. ex Bull. Soc. Bot. Fr. XXVI. p. 86.

Chærophyllum scabrum Thunb Fl. Jap. p. 119.

Nom. Jap. *Ogabujirami*.

Hab. in pratis campis prope Tokio (T. Makino et ipse. Medio Majo fl. Junio fr. mat!); Prov. Ise; Miyegori (K. Tani); Prov. Tosa in insula Shikoku: in pago Ochimura (T. Makino).

Adnot. Umbellae in speciminibus nostris semper 3-radiatae, nec 5—7 ut De Candolle descripsit.

Coriandrum L.

Coriandrum sativum L. *Nom. Jap. Koendoro.* Interdum in hortis japonensibus cultum. In Sinteck, formosa boreali, legit Honda.

Conium L.

Conium maculatum L. *Nom. Jap. Doku-zeri* Introductum.

Pleurospermum Hoffm.

Hoffm. Umb. p. VIII. XXXII; DC. Prodr. IV. p. 244; Endl. Gen. Pl. II. p. 791; Benth. et Hook. Gen. Pl. I. p. 915; Baillon Hist. d. Pl. VII. p. 210 (sub Meo); Drude in Nat. Pfl. Fam. Theil III. abt. VIII. p. 171.

Calycis dentes obsoleti v. parvi acuti; petala obovata integra apice obtusa v. acuta unguiculata; fructus a latere leviter compressus ovato-oblongus, stylopodio conico coronatus; mericarpia membrana duplici inclusa, interiora semini adnata; vittae ad valleculas solitariae vel interdum geminae, commissurales utrinque solitariae; carpophorum bipartitum; semen semi-lunare—Herbae perennes; folia bi-tripinnata, segmentis ovatis dentatis, involucra foliacea; umbellae ∝ radiatae.

Pleurospermum austriacum Hoffm. Umbellif. praem. X ; DC. Prodr. IV. p. 244 ; Spr. Syst. Veg. I. p. 894 ; Ledeb. Fl. Alt. I. p. 368, Fl. Ross. II. p. 360 ; Maxim. Prim. Fl. Amur. p. 130 ; Rupr. Rev. Umb. Kamtsch. p. 27 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 333 : Miyabe, Fl. Kurile Isl. in Mem. Bost. Soc. Nat. Hist. IV. n. VII p. 236.

Pleurospermum Kamtschaticum Hoffm. Umbellif. X ; DC. Prodr. IV. p. 244 ; Ledeb. Fl. Ross. II. p. 361 ; Fr. Schm. Fl. Sach. p. 140 ; Fr. et Sav. Enum. Pl. Jap. I p. 186.

P. uralense Hoffm. l.c. IX ; DC. l.c. ; Ledeb. Fl. Alt. I. p. 368 (nota) ; Fl. Ross. II. p. 361.

Ligusticum austriacum L. 360 edd. Willd. I. p. 1496.

Ligusticum foliis triplicato-pinnatis, pinnis pinnatifidis. Gmel. Fl. Sibir. I. p. 196. no. II. t. 45.

Planta 4—pedalis vel ultra ; caule cavo erecto angulato simplici vel subramoso vulgo glabro ad insertiones petiolorum et sub umbellis tantum puberulo ; foliis ternato-pinnatisectis, segmentis primariis petiolatis, secundariis subsessilibus circumscriptione ovatis pinnatifidis, laciniis ovato-oblongis inciso-dentatis ; involucris polyphyllis angustis foliaceis pinnatis ; umbellis 40-50-radiatis ; involucellis plurifoliolis lanceolatis inæqualibus umbellulis florentibus longioribus ; umbellulis multifloris, calycis dentibus acutis setulosis, petalis albis late obovatis, filamentis petalis subæqualibus v. longioribus, antheris albis, stylis erectis brevibus, stylopodio conico ; fructibus ovatis jugis primariis prominulis subdenticulatis integrisve ; valleculis univittatis, interdum intervalleculis 1-vittatis.

Nom. Jap. Onikasamochi, Ōkasamochi.

Hab. in graminosis humidis ins. Yezo et montanis Honsiu borealis.

Kurile—Ins. Etorofu ad Rubetsu (sec. Miyabe).

Hokkaidō (Yezo)—Prov. Hidaka: Saruru (Y. Tokubuchi); Prov. Iburi: Muroran (J. Matsumura); Prov. Ishikari: circa urbem Sapporo (K. Miyabe); Prov. Kushiro: in ignivomo Meakan (Kawakami); Prov. Kitami: in monte Rishiri (Herb. Kawakami).

Honshiu—Prov. Shinano: in monte Wadatoge (ipse); in monte Togakushi (Julio. 1884 fl!); Prov. Shimotsuke; in monte Nikkō (T. Makino)

Distr. Europa orient., Sibiria, Kamtschatka.

Bupleurum (Tourn) L.

L. Gen n. 328; Hoffm. Umb. p. 112; DC. Prodr. IV. p. 127; Endl. Gen. Pl. II. p. 772; Benth. et Hook. Gen. Pl. I. p. 886; Baillon. Hist. d. Pl. VII. p. 226; Drude in Nat. Pfl. Fam. Theil III abt. VIII. p. 180.

Diophyllum et Isophyllum Hoffm. Umb. p. 112.

Calycis margo obsoletus, petala rotunda integra involuta costa prominula subcucullata; fructus a latere compressus, stylopodio depresso, margine integro; juga filiformia v. alata, valleculae 1-3-vittatae v. evittatae; carpophorum 2-fidum; semen subteres facie planiusculum—Herbae perennes, folia integra infima graminea caulina saepe sessilia involucra nulla v. oligophylla, umbella composita; flores flavi.

1. **Bupleurum falcatum** L. Sp. 341; Willd. Sp. Pl. 1372; DC. Prodr. IV. p. 132; Sow. Engl. Bot. IV. p. 122; Forbes et Hemsl. Ind. Fl. Sin. I p. 327; Miq. Prol. Fl. Jap. p. 246; Hance in Journ. Bot. 1883 p. 321; Palibin, Consp. Fl. Kor. I.p. 97; Diel. in Engl. Bot. Jahrb. XXIX. p. 493. var scorzoneraefolium Ledeb. Fl. Ross. II p. 207.

B. chinense. DC. Prodr. IV. p. 128; Bretschn. Hist. Europ. Bot. Disc. Chin. 176.

B. scorzoneraefolium Willd. DC. l.c. p. 132; Maxim. Prim. Fl. Amur. p. 125; Franch. Pl. David. I.p. 137.

Caule glabro supra ramoso 2-4 pedali, foliis radicalibus et caulinis inferioribus petiolatis oblongis 10-15 cm. longis, summis sessilibus basi attenuatis lanceolato-linearibus subamplexicaulibus margine integris 5-7-nerviis; involucris 2-3-phyllis lanceolatis v. ovato-lanceolatis v. setulosis inæqualibus; umbellis 5-8-radiatis; involucelli foliolis 5 lanceolatis umbellulis vix brevioribus; umbellulis 10-multifloris, pedicellis 3 mm. longis, petalis flavis latis involutis, staminibus petalis longioribus, stylis brevibus, stylopodio depresso plano; fructibus pedicellos æquantibus, jugis primariis angustis, sectione transversale pentagonis, multi-vittatis.

Nom. Jap. Mishimazaiko, Kamakurazaiko.

Icon. Jap. Kiūkō-Honzo I. fol. 25 recto? ; Kawi III. fol. 20. recto; Honzōzufu VII. fol. 9 sub. Saiko; Somokuzusetsu V. fol. 41 sub. Mishima-zaiko, Niraba-zaiko; Honzōkomoku-keimōzufu IX. fol. 8.

Hab. per totam Japoniam temperatam

Honsiu—Prov. Iwashiro: in pratis Iwase (ipse); Prov. Hitachi: Yūki; in monte Tsukuba; Prov. Kazusa: Ichinomiya (Augusto fl.); Prov, Musashi: circa Tokyo et in monte Takao; Prov. Sagami: Misaki (ipse), in monte Oyama (Herb. Mus. Imp.), in monte Hakone (S. Okubo et ipse); Prov. Izu in monte Omuro; Prov. Suruga: in radice montis Fuzi; Prov. Ise; in monte Kasaka; Prov. Izumi: in monte Hibaragoye (S. Matsuda Octobri fl. fr!); Prov. Harima: Kashimamura (U. Ogami).
Shikoku—Prov. Awa: In monte Takakoshiyama (N. Oyatsu); Prov. Tosa: ad montem Imosegoye (S. Yano).
Kiusiu—Prov. Higo: in ignivomo Aso (ipse).
Liukiu: loco non indicato (Herb. Mus. Imp).
Formosa: Byolitsu (A. Tashiro Junio anno 1897 no. A. 54!); Chukoo (Honda Augusto 1897).

Distris. In China boreali et Korea, India Orientali, Asia Occidentali et centrali, Europa australi.

Planta ex insula Formosa a me visa descriptione Clarkei abhorret foliis lineari-lanceolatis, involucri foliolis inæqualibus.

2. **B. sachalinense** Fr. Schmidt. Reis. Ins. Sach. p. 134 ; Fr. et Sav. Enum. Pl. Jap I. p. 179.

B. aureum Miq. Prol. Fl. Jap. p. 246 (teste Fr. Schmidt).

Herba perennis 2-6-pedalis glabra ; caule erecto ramoso ; foliis radicalibus petiolatis superioribus sessilibus lanceolato-oblongis v. elongato-ovatis 10-12 cm. longis integris, apice acutis v. obtusis, basi in petiolum attenuatis aut auriculatis v. cordatis amplexicaulibus quasi perfoliatis ; involucris 1-2-phyllis parvis oblongis ; umbellis 5-7-radiatis ; involucellis subpentaphyllis ovatis vel lanceolatis acutis 2-3-nerviis pedicellis longioribus ; umbellulis 10-12-floris, petalis flavis oblongis involutis, filamentis petalis longioribus ; fructibus oblongis jugis filiformibus c. 3 mm. longis, vittis parvis ad valleculas 3-multi. pedicellis floribus 1 ½—3 mm. longis.

Nom. Jap. Maruba-zaiko, Hotaruzaiko, Hotarusô.

Icon. Jap. Kawi, I. fol. 10. sub Hotaruso ; Honzōzufu VII fol. 10 recto ; Sōmokuzusetsu V. fol. 44 ; Honzōkomoku-keimōzufu IX fol. 8. verso.

Hab. in graminosis Japoniae borealis et temperatae.

Kurile—Ins. Shikotan (Herb. Kawakami).

Hokkaidō (Yezo)—Prov. Oshima ; Hakodate (Matsumura et Yatabe) : Prov Shiribeshi : Zenibako (K. Miyabe et Tokubuchi) ; Prov. Ishikari : ad ripas fluvii Toyohira prope Sapporo (J. Matsumura). Ishikari (Kawakami) ; Prov. Iburi : Oshamanbe (Kawakami).

Honshiu—Prov. Mutsu : in litore Kanegasawa tractus Aomori ; Prov. Rikuzen : Obara (ipse) ; Prov. Shimotsuke : in alpibus Nikkō (Augusto fl.) ; in pago Fujiwara mura (K. Nemoto) ; Prov. Iwashiro : Iwase (ipse) ; Prov. Shinano : ad pedes ignivomis Asama (ipse), in monte Shiojiri, in montibus Togakushi et Akadake (V.S.) ; Prov. Echigo : ins. Awojima (K. Yendō) ; Prov. Musashi : circa Tokyo (August. fl. Octobri fr. mat!) ; Prov. Sagami (sec. Savatier) ; Prov. Suruga : Murayama ; Prov. Yamashiro : in monte Hiyei (T. Makino Novembri fr.)

3. **B. multinervis** DC. var. **minor** Ledeb. Fl. Ross. II. p. 265.

B. multinervis DC. in Miq. Prol. Fl. Jap. p. 246 ; Fr. et Sav. Enum. Pl. Jap. I. p. 179.

Herba perennis, caule erecto gracili 1-2-pedali, foliis inferioribus lanceolatis in petiolos attenuatis, superioribus sessilibus ovatis basi cordatis amplexicaulibus apice acutis 5-nerviis ; involucris oligophyllis ovatis inæqualibus, umbellis 4-6-radiatis radiis 3-5-cm. longis ; involucellis subpentaphyllis lanceolato-ovatis v. suborbiculatis viridibus umbellulam florentem parum superantibus ; umbellulis 10-floris, pedicellis brevibus fructibus oblongis 3 1/2 mm longis, jugis primariis acutis, valleculis 2-3-vittatis, commissuris utrinque 2-vittatis.

Nom. Jap. Hakusan-zaiko, Tōgokuzaiko.

Icon. Jap. Sōmoku-zusetsu V. fol. 42 ; Honzō-zufu VII. fol 11 sub Hotaruso.

Hab. Hokkaidō—Prov. Hidaka Saruru (Yatabe), Horoizumi (Tokubuchi).
Honshiu—Prov. Shinano : in tractu Kiso (Yatabe) ; in monte Shirouma (ipse).

Distr. Sibiria.

4. **B. triradiatum** Adans. var. **alpinum** Rupr. Rev. Umb. Kamtsch. in Beitr. Pfl. Russ. Reich. pt. XII p. 26 ; Fr. Schmidt Fl. Sach. p. 135.

Herba perennis 1/2-1/3-pedalis ; foliis radicalibus oblongo-spathulatis 7-nerviis basin versus attenuatis subamplexicaulibus, caulinis obovatis vel oblongis ; foliis et involucri foliolis subtus glaucis ; involucris triphyllis orbiculatis ovatisve 1 cm. longis, 8 mm. latis multinerviis inæqualibus ; umbellis 3-5-radiatis ; involucelli phyllis 5-6 oblongo—orbiculatis vel oblongis multinerviis apice mucronatis coloratis viridibus subtus glaucis 5 mm. × 3-5 mm. umbellulam superantibus ; pedicellis brevibus 1-2 mm. longis

umbellulis 10-15-floris, petalis ovatis involutis, staminibus petalis subæqualibus, stylis brevissimis, stylopodio depresso margine integro: fructibus oblongis jugis parum elatis.

Nom. Jap. Repunzaiko.

Hab. Yezo—Ins. Repun (S. Hori Augsto 1887. fr. juven.) Ins. Rishiri (Communic T. Kawakami).

Distr. Kamtschatka, Sachalin.

Apium L.

Linn. Gen. n. 367 ; Willd. Sp. Pl. p. 1475 ; Hoffm. Umbellif. I. p. 75 ; DC. Prodr. 100. 104 ; Benth. et Hook. Gen. Pl. I. p. 888 ; Endl. Gen. Pl. II. p. 794 ; Baillon, Hist. d. Pl. VII. p. 212 ; Drude in Nat. Pfl. Fam. theil III. abt. VIII. p. 184.

Helosciadium Koch. Umb. 125 ; DC. l.c. 104.

Flores hermaphroditi ; calycis margo obsoletus, petala ovata v. subrotunda integra vix acuminata cum lacinula brevi-inflexa, stylopodia depressa margine integra ; fructus ovato-orbiculatus v. oblongus a latere leviter compressus, ad commissuram constrictus basi rotundatus v. sæpius plus minus emarginatus ; mericarpia 5-gona, jugis primariis prominulis subæqualibus, vittae ad valleculas solitariae ; carpophorum indivisum v. apice bifidum v. nullum ; semen facie planum v. convexum—Herbae annuae v. perennes, folia pinnata v. decomposita, umbellae oppositifoliae v. terminales, involucri bractea pauca ; involucella ∞—phylla v. nulla ; flores albi.

1. **Apium graveolens** L. In hortis Tokyoensibus saepe cultum. Formosa—Takaw (cult! sec. Henry) ; Sinteck (Hiraoka).

2. **A. Ammi** Urb. in "Marti. Fl. Brasil. vol. XI. fasc. I. p.

341 pl. 9 (1879)"; Drude. Umb. p. 175 fig. 64 A-C ; Lœsener. Pl. Selerian. in Bull. Herb. Boiss. II. p. 552 ; K. Reiche in Engl. Bot. Jahrb. XXVIII, heft. I. t. 1. fig. 35 ; Coult. et Rose, Synop. Mex. and Cent. Am. Umb. p. 144 (1900).

Apium leptophyllum F. v. Muell. Fragm. Phytog. Austr. VII. p. 148 ; Benth. Fl. Austr. III p. 372 ; Hook. Biol. Centr. Am. I. p. 566 ; Coult. et Rose, Rev. N. Am. Umb. p. 124 ; Coult. in Contr. U. S. N. Herb. II. 1. p. 147 ; Britton et Brown Ill. fl. S. U. S. et Canad. II. p. 534.

Helosciadium leptophyllum DC. Prodr. IV. p. 104 ; Griseb. Fl. Br. West. Ind. isl. p. 308.

Helosciadium laterifolium Koch. Hook. et Arn. Bot. Beech. Voy. p. 26.

Æthusa Ammi Spr. Umbel. Prodr. 22.

Herba annua, caule tereti ramoso glabro sicco striato pedali ; foliis ternatim bi-tripinnatis, segmentis angustissimis linearibus $1^1/_2$ cm. longis 1/2 mm. latis ; petiolis basi dilatatis amplectentibus margine membranaceis ; ramis axillaribus ; umbellis oppositifoliis sessilibus, vulgo bi-, rarius tri-radiatis, radiis æquilongis ; involucellis nullis ; umbellulis 5—7-floris, pedicellis æquilongis 4—5 mm. longis ; calycis dentibus obsoletis, petalis albis lato-ovatis apice acutis leviter inflexis ob costam constrictis, staminibus petalis brevioribus, stylis brevissimis, disco parvo ; fructibus minutis ovatis $1^1/_2$ mm. longis pedicellis triplo brevioribus a latere compressis jugis primariis omnibus æqualibus crassis, valleculis uni-vittatis, commissuris bi-vittatis ; seminibus sectione suborbiculatis ; carpophoris apice breviter bi-fidis.

Nom. Jap. Matsuba-zeri.

Hab. Kiusiu—Prov. Hizen : Mogi haud procul a Nagasaki (S. Ikeno, Herb. Acad. Dend. 6. Augusto anno 1894, fl. fr.); circa Nagasaki frequens. (ipse 19 Julio anno 1901) forsan introductum !

Subgen. **Apodicarpum**

A. Ikenoi (Makino) Drude. Herba perennis glabra 1—1/2 pedalis gracilis, radice tuberifera fibris fasciculatis; caule erecto glabro sulcato cavo subramoso; foliis 10—12-cm. longis pinnatisectis 5—7-foliolis, segmentis lateralibus ovatis v. lanceolato—ovatis basi cuneatis, terminalibus latis saepe 3-lobatis, apice acutis inciso-serratis; petiolis in vaginas attenuatis membranaceis; umbellis terminalibus 5—7-radiatis, radiis inæqualibus nunc 1/2—1 cm. longis nunc brevissimis subsessilibus; involucris 1—oligophyllis, phyllis setuloso-lanceolatis v. pinnatisectis; involucelli foliolis 2—3; umbellulis 5—10-floris, pedicellis inæqualibus; calycis lobis obsoletis, petalis albis ovato-orbiculatis apice acutis cum lacinula brevi-inflexis; stylis brevibus, stylopodio depresso; fructibus ovalibus a latere compressis ad commissuram constrictis basi rotundatis 2 1/2 mm. longis; mericarpiis jugis primariis angustis prominulis; valleculis 1—, commissura utrinque 1-vittatis, carpophoro nullo.

Apodicarpum Ikenoi Makino Ill. Fl. Jap. vol. I. n. IX. t. 58.

Apium Ikenoi Drude in Engl. et Prantl. Nat. Pfl. Fam. theil III. abt. VIII. p. 185.

Nom. Jap. Yekisai-zeri.

Hab. Prov. Musashi: in graminosis ad Toda, propo Tokyo. (S. Ikeno, T. Makino, ipse. Majo fl. initio juni fr.)

Petroselinum Hoffm.

Petroselinum sativum Hoffm. Rarius cultum.

Cicuta L.

Linn. Gen. n. 354; Willd. Sp. Pl. p. 1445; Hoffm. Umb.

I. p. 177 ; DC. Prodr. IV. p. 79 ; Endl. Gen. Pl. II. p. 768 ; Benth. et Hook. Gen. Pl. I. p. 889 ; Baillon, Hist. d. Pl. VII. p. 211 ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 187.

Calycis limbus acute triangularis ; petala obovata v. obcordata acuminata inflexa ; stylopodia depressa integra ; fructus late ovatus didymus latior quam longus, ad commissuram constrictus, mericarpia 5-juga crassa ; vittae ad valleculas angustas solitariae ; carpophorum bi-partitum ; semen transverse teres a dorso plus minus compressum.—Herbae perennes, glabrae ; folia bi-tripinnatisecta v. pinnatim decomposita ; umbella composita multi-radiata ; flores albi ; involucri involucellique foliola saepe 0.

Cicuta virosa L. Sp. p. 368 ; Willd. Sp. Pl. p. 1445 ; Aiton, Hort. Kew. II. p. 149 ; Spr. Syst. Veg. I. p. 894 ; DC. Prodr. IV. p. 99 ; Sow. Engl. Bot. 479 ; Ledeb. Fl. Alt. I. p. 359 ; Ibid. Fl. Ross. II. p. 241 ; Rupr. Rev. Umb. Kamtsch. p. 24 ; Maxim. Prim. Fl. Amur. p. 124 ; Fr. Schmidt, Fl. Sach. p. 134 ; Miq. Prol. Fl. Jap. p. 245 ; Coult. & Rose, Rev. N. Am. Umb. p. 129 ; Fr. et Sav. Enum. Pl. Jap. I. p. 80 ; Forb. et Hemsl. Ind. Fl. Sin. I. p. 328.

Cicutaria aquatica Lam. Illustr. t. 195.

Sium pinnis laciniatis, pinnulis trifidis, nervo non folioso. Gmel. Fl. Sib. I. p. 202. no. 16.

Radice cavo septato, caule erecto glabro fistuloso ramoso 3—4-pedali ad nodum petiolumque atropurpureo, foliis saepissime tripinnatisectis, segmentis oblongo-lanceolatis aut lanceolatis acutis serratis ; petiolis plus minus amplexicaulibus ; umbellis oppositifoliis terminalibusque 10—15-radiatis ; involucris nullis v. 1—2-phyllis ; involucelli foliolis 8—9 linearibus umbellis æqualibus interdum

longioribus ; umbellis multifloris, pedicellis fructibus duplo longioribus, calycis lobis acutis, petalis albis obcordatis inflexo-acuminatis fructibus orbiculatis valleculis uni-vittatis.

Folia inferiora circa 60 cm. longa, subtus glaucescentia, serrata, serraturis acutis ; pedunculi 4—2 cm. longi, pedicelli 1/2 cm. stamina petalis longiora ; umbellae terminales tantum fructiferae.

Nom. Jap. Doku-zeri.

Icon. Jap. Sōmoku-zusetsu V. fol. 12 sub Ōzeri.

Hab. Hokkaidō (Yezo)—Prov. Oshima: ad ripas fluvii circa Hakodate (R. Yatabe, J. Matsumura); Prov. Ishikari: Sapporo et Sorachibuto (Herb. Kawakami): Prov. Iburi: Oshamambe (Kawakami).
Kurile—Shana in ins. Etorofu.
Honsiu—Prov. Shinano: in fossis; circa radicem ignivomi Asama (ipse); in monte Wadatōge (ipse); Prov. Yamashiro: Uzi (K. Nagano. Majo fl.)
Kiusiu—Prov. Higo: circa Kumamoto (K. Nakagawa in herb. Makino).

Distr. China—Chili : prope Peking ; Shingking: ad Ngantunghsien in Chiu-lien Chieng (K. Jimbo, Julio 1895). Tota Europa : Asia per regiones temperatas ; in America boreali.

Cicuta nipponica Franchet. Bull. Soc. Bot. Franc. Tom. XXVI, p. 84. (1879) ; Fr. et Sav. Enum. Pl. Jap. II. p. 736.

Caule striato-sulcato glabro purpurascenti ramoso ; foliis inferioribus bipinnatisectis, segmentis subsessilibus lanceolato-oblongis v. ovato-lanceolatis basi rotundatis v. cuneatis argute inciso-serratis 2—$2^1/_2$ cm. latis, 8—12 cm. longis subtus glaucescentibus, segmentis foliorum superiorum angustis ; involucro nullo ; umbellis oppositifoliis 25—30-radiatis, radiis glabris 8 cm. longis ; umbellulis multifloris, calycis dentibus acutis, petalis obcordatis, staminibus petalis duplo longioribus, stylopodio depresso, stylis brevibus dein elongatis reflexis ; fructibus orbiculatis 2 mm. latis, jugis primariis vix prominulis. vittis valleculis solitariis.

Nom. Jap. *Ōzeri.*

Hab. Prov. Musashi: circa Tokyo rarissima; Prov. Etchigo: in locis humidis circa Niigata (R. P. Fauriae. Sec. Franch.)

Antecedenti valde affinis. sed folia fructusque majora, dentibus foliolorum subæqualibus.

Cryptotænia DC.

DC. Prodr. IV. p. 118; Endl. Gen. Pl. p. 771; Benth. et Hook. Gen. Pl. I. p. 898; Baillon, Hist. d. Pl. VII p. 120; Drude in Nat. Pfl. Fam. III. abt. VIII p. 189.

Deringia, Adanson "Fam. Pl. II. p. 498; O. Kunze. p. 266"; Britton et Brown. Ill. Fl. N. St. Can. II. p. 59.

Calycis margo obsoletus; petala obovata v. obcordata cum lacinula inflexa; discus stylopodio breviconic coronatus; fructus oblongus a latere compressus; mericarpia jugis 5 æqualibus filiformibus, 2 lateralibus ante marginem positis; vittae valleculae et commissurae parvae subcorticae; semen tereti facie planiusculum—Herbae perennes glabrae erectae, folia ternata segmentis ovatis; umbellae numerosae subpaniculatae radiis valde inæqualibus; involucrum nullum v. 1-phyllum, involucella oligophylla; flores albi.

Cryptotænia japonica Hassk. "Retz. I. 113"; Maxim. Mel. biol XII. p. 467; Ito et Matsumura, Tent. Fl. Lutch. I. p. 528.

Cryptotaenia canadensis S. et Z. (non DC.) Fl. Jap. Fam. Nat. n. 424; A. Gray, Bot. Jap. p. 391; Miq. Prol. Fl. Jap. p. 246; Hance in Journ. Bot. III. p. 340, V. p. 114 et VIII. p. 276; Fr. et. Sav. Enum. Fl. Jap. I. p. 182; Forbes et Hemsl. Ind. Fl. Sin. I p. 329.

Sison canadense Thunb. Fl. Jap. p. 118.

Caule erecto glabro ramoso 1—2 pedali: foliis trisectis segmentis

sessilibus oblongis v. rhombeis inciso-dentatis ; petiolis basi amplexicaulibus gramineis ; involucris 1—2 minutis setaceis v. 0 ; umbellis paniculatis 2—3-radiatis ; involucellis 2—3-phyllis linearibus setaceis ; umbellulis 2—4-floris ; calycis dentibus obsoletis, petalis albis oblongis obovatis apice acutis inflexis ; filamentis petalis æquilongis, antheris albis, stylis erectis petalis vix brevioribus ; fructibus oblongis.

Nom. Jap. Mitsuba-zeri.

Icon. Jap. Sōmoku-zusetsu V. fol. 30 ; Shitsumon-honzōgaihen I. t. 9.

Hab. Vulgo culta. In humidis sylvaticis ubique dispersa.

Hokkaidō (Yezo)—Prov. Iburi : Mororan (J. Matsumura), Oshamanbe (Herb. Kawakami) ; Prov. Ishikari : Sapporo (Kawakami).

Honsiu—Prov. Mutsu : in campis Tokiwano ; Prov. Iwashiro : in tractu Aizu (R. Yatabe) ; Prov. Shinano : in monte Usui (ipse), in monte Wadatōge (ipse), loco non indicato (Takashima) ; Prov. Musashi : in fruticetis udis circa Tokyo (Augusto. fl. et fr !), in montibus Takao et Mitake (ipse) ; Prov. Sagami : in jugo Hakone (ipse) ; Prov. Suruga : in monte Fuzi (N. Ōno), Murayama (J. Matsumura) ; Prov. Kawachi : in monte Kongōsan (T. Tada) ; Prov Izumi : Tonohara (S. Matsuda) ; Prov. Harima. Kashimamura (U. Ogami) ; Prov. Hōki : in monte Taisan.

Shikoku—Prov. Awa : Mitsumura ; Prov. Tosa : in monte Yahazu (R. Yatabe).

Kiushiu—Prov. Chikuzen : Ōkawamura in Kasuyagōri (K. Nagano) ; Prov. Hiuga : in ignivomo Kirishima ; Prov. Bungo : Makino-kuchi (S. Satō) ; Prov. Higo : in monte Aso (ipse) ; Ins. Tsusima (ipse).

Liukiu—Ins. Okinawa : prope Shuri (K. Miyake, A. Tashiro, T. Ito) ; Archipelago Yayeyama (A. Tashiro) ; Ins. Kurushima (A. Tashiro).

Distrib. China—Kiansi, Hupeh, Kwantung, Hanchow (C. Owatari !).

var. dissecta m. Perennis glabra, caule cavo erecto gracili ; foliis ambitu deltoideis trisectis, segmentis subsessilibus glabris profunde pinnatilobis lobis elongato-oblongis inciso-serratis, serraturis apice mucronatis ; petiolis inferioribus longis basi dilatatis amplexicaulibus superioribus membranaceis; umbellis paniculatis multi-radiatis, involucris 1—2 phyllis setaceis ; umbellulis laxifloris, calycis margini-

bus obsoletis, petalis albis oblongis apice leviter inflexis ; staminibus petalis æqualibus, antheris albis, stylis erectis petalis vix brevioribus ; fructibus.........(immaturis !).

Nom. Jap. Ushi-mitsuba (sec. Keiske Itō).

Hab. in umbrosis sylvaticis, ad pedem ignivomi Fuji (N. Ōno. Augusto anno 1895) ; Prov Shimotsuke : in alpibus Nikkō (K. Ito !).

Observ. Antecedenti valde affinis, sed segmentis foliorum pinnatifidis inciso-serratisque differt.

Carum L.

Linn. Gen. n. 365 ; Willd. Sp. Pl. p. 1470 ; Hoffm. Umb. I. p. 84 ; Koch, Umb. 121 ; DC. Prodr. IV. p. 114 ; Endl. Gen. Pl. p. 471 ; Benth. et Hook. Gen. Pl. I. p. 890 ; Baillon, Hist. d. Pfl. VII. p. 219 ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 191.

Calycis dentes obsoleti v. parvi ; petala obovata cum lacinula inflexa ob costam superne intrusam v. 2-lobata ; stylopodia conica depressa margine integra; fructus elongato-ovatus a latere compressus ; mericarpia 5—juga, jugis prominulis æqualibus lateralibus marginatis; valleculae 1—, commissurae 2-vittatae, carpophorum bifidum partitumve, semen facie convexum v. planum—Herbae annuae v. perennes, folia pinnata vel pinnatim decomposita, involucra involucellaque nulla vel oligophylla parva ; flores albi.

1. **Carum Carvi** L. Cult. !

2. **C.** (Edosmia) **neurophyllum** (Maxim) Fr. et Sav. Enum. Pl. Jap. I p. 180.

Edosmia neurophyllum Maxim. in Mel. biol. IX. p. 16.

Herba perennis, radice tuberosa, caule erecto sulcato 3—6-pedali paucifolio; foliis inferioribus bi-multi-pinnatisectis, segmentis lanceolatis linearibus; foliis mediis et superioribus pinnatisectis 1—3-jugis, segmentis omnium foliorum linearibus apice acuminatis integris 3-nerviis, nervis lateralibus marginantibus: petiolis basi dilatato-subamplexicaulibus; umbellis compositis 8—12-radiatis; involucris 5—8-phyllis linearibus; involucelli foliolis 7—8 linearibus umbellulis florentibus brevioribus; umbellulis 10—multifloris, calycis lobis ovatis triangulatis, pedicellis fructibus duplo superantibus; fructibus oblongis 5-jugis, valleculis 1-vittatis; carpophoris bipartitis.

Nom. Jap. Shimura-ninjin.

Icon. Jap. Sōmoku-zusetsu. v. fol. 29; Nippon-sambutsushi. pt. Musashi. B. fol. 9.

Hab. Prov. Musashi: in graminosis ad Shimura circa Tokyo (ipse. initio August. fl. et fr.); Prov. Shimosa: in paludosis et orizetis ad Mama prope Tokyo; Kiusiu, in Kundshōsan sylvis udis Cryptomeriae (sec. Maxim).

3. **Carum holopetalum** Maxim. in Mel. biol. XII. p. 46.

Caule erecto fistuloso sulcato ramoso 3 pedali; foliis biternatisectis, segmentis petiolulatis ultimis ovatis 2—3-fidis, laciniis integris, acutis v. apiculatis; umbellis 10—12-radiatis, involucris paucifoliis filiformibus; involucelli foliolis 5—8 acutis linearibus v. subulatis; umbellulis multifloris, calycis limbis acutis, petalis obovatis cum lacinula brevi inflexa, stylopodio depresso; fructibus ovalibus oblongis jugis filiformibus; mericarpiiss ectione transversali pentagonalibus valleculis 1-vittatis; commissuris minutis 2-vittatis, carpophoris bipartitis.

Nom. Jap. Ibuki-zeri.

Icon. Jap. Sōmoku-zusetsu. v. fol. 26.

Hab. Hokkaidō (Yezo)—Prov. Oshima: Sasayama, prope opidulum Yesashi (K. Miyabe).

Honshiu—Prov. Mutsu; in monte Iwakiyama; Prov. Ugo: in monte Gassan; Prov. Iwashiro: in monte Iidesan (R. Yatabe et J. Matsumura); Prov. Kaga: in monte Hakusan (R. Yatabe. Augusto fr.)

4. **C.** (Cryptotaeniopsis) **Tanakae** Fr. et Sav. Enum. Pl. Jap. II. p. 370; Franch. Note Sur Quelque Omb. d. Yunnan. p. 17 (extrait d. Bull. d. Soc. Philom. Paris. 1894).

Pimpinella Tanakae Diels, in Engl. Bot. Jahrb. XXIX. p. 494.

Carum filicinum Fr. Bull. Soc. Philom. Paris 8. sér. VI. p. 121.

Pimpinella filicina Diels, Engl. Bot. Jahrb. XXIX. p. 494.

Chamæla ? Tanakae Fr. et Sav. l. c. I. p. 185.

Rhizoma crassum cylindricum interdum ramosum; caule humili c. 1/2 pedali gracili erecto simplici glabro; foliis radicalibus longe petiolatis circumscriptione deltoideis bipinnatisectis v. biternatis, segmentis plerumque subsessilibus petiolulatisve oblongis v. cuneato-oblongis 3—5-fidis, lacinulis apice mucronulatis petiolis elongatis basi late dilatatis; foliis caulinis tantum uni- v. biphyllis nunc bipinnatisectis, segmentis anguste lanceolatis v. lanceolato-linearibus; umbellis terminalibus solitariis 8—10 v. 20-radiatis. radiis filiformibus subæquilongis patentibus; involucris 0. v. 1 setaceis, involucelli foliolis 1—2 parvis setaceis; umbellulis 2—3-floris brevipedicellatis, calycis dentibus obsoletis; petalis albis ovatis; stylis brevibus stylopodio conico; fructibus oblongis a latere compressis 2 mm. jugis 5 primariis tenuibus; valleculis 1-vittatis commissulis utrinque 1-vittatis, carpophoris bi-partitis.

Nom. Jap. Iwasentōsō (sec. T. Makino).

Hab. In sylvis opacis alpibus Japoniae mediae.

Prov. Shimotsuke: in monte Nikkō (Junio fl. julio fr!); Prov. Shinano in monte Togakushi et aliis montibus; Prov. Suruga: in monte Fuji; in ins. Shikoku: Prov. Tosa, in monte Tebako (T. Makino).

Distrib. China centrali.

Aegopodium L.

Linn. Gen. n. 368 ; Willd. Sp. Pl. p. 1476 ; Hoffm. Umb. p. 80 ; DC. Prodr. IV. p. 114 ; Endl. Gen. Pl. p. 771 ; Benth. et Hook. Gen. Pl. I. p. 893 ; Drude, Nat. Pfl. Fam. III. abt. VIII. p. 196.

1. **Aegopodium podagraria** L. Sp. 379 ; Willd. Sp. Pl. p. 1476 ; Hoffm. Umbellif. I. p. 82 ; DC. Prodr. IV. p. 114 ; Ledeb. Fl. Alt. I. p. 354 ; Fl. Ross. II. p. 247 ; Coult. et Rose, Rev. N. Am. Umb. p. 133.

A. foliis caulinis summis ternatis. Gmel. Fl. Sib. I. p. 220 no. 31.

Pimpinella angelicaefolia Lam. Encycl. I. p. 451.

Sison podagraria Spreng. Syst. Veg. I. p. 886.

Caule erecto sulcato-angulato glabro, foliis bi-triternatis v. pinnatis, segmentis petiolulatis terminalibus sæpe trisectis ovato-oblongis basi rotundatis v. cordatis serratis, serraturis mucronulatis, superioribus ternatis oblongis v. oblongo-lanceolatis, laminis glabris subtus glaucescentibus, ad nervos puberulis ; involucri et involucelli foliolis nullis; umbellis 15—20-radiatis, radiis 3—4 cm. longis sulcatis, caulibus summis et radiis interne puberulis ; umbellulis 20—30-floris, petalis albis obovatis unguiculatis, stylis petalis subæquilongis dein reflexis, fructibus ovato-oblongis.

Nom. Jap. Iwamitsuba.

Hab. Prov. Shinano? (In horto Bot. Tokyoensi cultum.)

Distrib. In sepibus Europae totius, in Rossia et Sibiria.

2. **A. alpestre** Ledeb. Fl. Alt. I. p. 354 ; Fl. Ross. II. p. 248 ; Reg. et Til. Fl. Ajan. p. 96 ; Trautv. & Mey. Fl. Ochot. p. 43 ;

Maxim. Primit. Fl. Amur. p. 124; Fr. Schmidt. Fl. Sach. p. 135; Benth. et Hook. Gen. Pl. I. p. 893; Miyabe, Fl. Kurile Isl. in Mem. Bost. Soc. Nat. Hist. IV. n. VII. p. 235; Trautv. Pl. Sibir. Bor. in Acta. Hort. Petr. v. p. 61; Diel. Fl. Centr. China. in Engl. Bot. Jahrb. XXIX. p. 497.

Pedale, caule glabro erecto oligophyllo; foliis bi-tripinnatisectis, segmentis ovatis superioribus augustis argute serratis, serraturis mucronulatis, petiolis inferioribus elongatis basi dilatato-attenuatis, superioribus amplis vaginatis; involucris nullis rarissime 1 setaceis; umbellis 8—12-radiatis, radiis 1—3 cm. longis, involucellis nullis; umbellulis 10-multifloris, petalis oblongis v. obovatis apice emarginatis, filamentis petalis duplo longioribus; stylis erectis dein reflexis; fructibus ellipticis 2 mm. longis jugis filiformibus.

Hab. Kurile—Ins. Shikotan (sec. Miyabe.)
Hokkaidō (Yezo)—Ins. Rishiri (S. Hori et T. Kawakami); Prov. Ishikari: Sapporo (K. Miyabe, Y. Tokubuchi et T. Kawakami, A. Ideta); Prov. Nemuro: Otsuishi (R. Yatabe); Prov. Hidaka; Saruru (K. Miyabe).
Honsiu—Prov. Uzen: Rokujurigoye (Augusto 1887. fl).

Distr. In Sibiria altaica, baikalensi et ochotensi; Manchuria; Sachalin.

Subgen. **Chamæle.**

Chamaele Miq. Prol. Fl. Jap. p. 247; Fr. et Sav. Enum. Pl. Jap. I. p. 184 et II. p. 374.

Calycis margo obsoletus; petala orbiculato-oblonga v. obovata apice unguiculata cum lacinula brevi-inflexa; stamina suberecta petalis subæqualibus, filamentis subulato-filiformibus antheris ellipticis didymis; styli breves suberecti dein deflexi; stylopodium leviter compressum margine integrum; fructus obovato-oblongus a latere (nec a dorso ut cl. Miquel descripsit) compressus, ad commissuram

parum constrictus; mericarpia sectione subpentagona, jugis primariis vix prominulis 2 marginantibus, vittae nullae, semen sectione suborbiculatum, facie convexum, carpophorum bipartitum.——Herbae perennes, caule aphyllo scapiformi, folia bi-tripinnatisecta, umbella terminalia pauci-radiata; involucra involucellaque nulla, flores albi.

A. (Chamaele) **tenera** (Miq.) Caule humile 20—30 cm. longo erecto gracili glabro folia superanti scapiformi; foliis fere omnibus radicalibus petiolis gracilibus 10—15 cm. longis canaliculatis basi vaginatis; laminis foliorum bi-tripinnatisectis, segmentis primariis distincte petiolulatis, secundariis brevipetiolulatis v. subsessilibus, ultimis cuneatis ad apices 3—5-dentatis fissis lobatisve; umbellis terminalibus 3—5-radiatis, radiis inaequilongis unico saepe subsessile; involucro involucelloque nullo; umbellulis 5—8-floris, calycis lobis obsoletis, petalis albis oblongis apice unguiculatis a medio leviter constrictis; staminibus petalis subaequalibus, antheris albis demum brunneis didymis, stylis brevibus deflexatis elongatis reflexis, stylopodio depresso; fructibus ovato-oblongis a latere valde compressis; mericarpii unis lateralibus rarius abortis; jugis primariis omnibus filiformibus, ambitu subpentagonalibus evittatis; seminibus transverse teretibus, facie convexis, carpophoris bipartitis.

Chamaele tenera Miq. Prol. Fl. Jap. p. 247; Fr. et Sav. Enum. Pl. Jap. I. p. 184 et II. p. 374.

Sium decumbens Thunb. Fl. Jap. p. 118.

Nom. Jap. *Sentosō.*

Icon. Jap. Sōmokuzusetsu, v. fol. 16.

Hab. In umbrosis sylvaticis per totam Japoniam. Aprili fl. Versus Maji exitum fructus mat.

Hokkaidō (Yezo): Prov. Hidaka; Horoizumi (K. Yatabe); Prov. Ishikari: circa Sapporo (K. Miyabe, T. Kawakami); Prov. Kushiro: in ignivomo Meakan (T. Kawakami).

Honshiu—Prov. Rikuzen: in monte Omori (Herb. Yasuda), in monte Taihaku-san (K. Yendō); Prov. Shimotsuke: in alpibus Nikkō (K. Nagano et Ipse); Prov. Musashi: in montibus Chichibu, Takao et Mitake, circa Tokyo (ipse); Prov. Sagami: in monte Oyama (Herb. Mus. Imp.), Hakone (ipse); Prov. Awa: in monte Kiyosumi (Herb. Mus. Imp.); Prov. Izu: in monte Amagi (S. Okubo); Prov. Ise: Nishiura circa oppidulum Tsu (K. Tani); Prov. Kaga: Ichinoshiku (T. Ichimura).

var. japonica (Makino). Radice fibrosa, caule humile glabro striato foliis duplo longioribus; foliis omnibus radicalibus longe-petiolatis pinnatim decompositis, laciniis augustis lanceolato-linearibus apice mucronullatis, petiolis basi dilatatis, vaginiis ampliatis hyalo-membranaceis; involucris involucellisque nullis, umbellis 3-radiatis fere omnibus pedunculatis; umbellulis 3—5-floris, calycis dentibus obsoletis; petalis albis oblongis apice obtusis plus minus involutis; staminibus petalum æquantibus, antheris albis flavescentibus demum testaceis, stylis longis erectis defloratis deflexis; fructibus 5-gonalibus vittis nullis, jugis vix conspicuis, carpophoris bipartitis.

Caulis circa 15 cm. longus; folia 10 cm. longa; pedunculus 2—3 cm., fructus $1\frac{1}{2}$ mm., pedicellus 1—2 mm. Precedenti proxima, a qua tamen statim differt segmentis foliorum augustis, umbellis fere omnibus pedunculatis 3-radiatis; antheris albo-flavescentibus.

Chamaele japonica Makino (mss.).

Nom. Jap. Miyama-Sentōsō; Hosoba-Sentōsō.

Icon. Jap. Sōmoku-zusetsu. V. fol. 17.

Hab. Prov Owari? In horto botanico Tokyoensi culta. Aprili fl. Majo fr. mat!

Pimpinella L.

Linn. Gen. n. 366; Hoffm. Umb. I. p. 88; DC. Prodr. IV p. 119; Benth. et Hook. Gen. Pl. I. p. 893; Endl. Gen Pl. II. p. 771; Baillon, Hist. d. Pl. VII p. 119; Drude in Nat. Pfl. Fam. III abt. VIII. p. 195.

Calycis dentes obsoleti; petala obovata v. ovata cum lacinula inflexa; fructus glaber ovatus a latere compressus basi emarginatus apice subcapitatus, stylopodium latum conicum; mericarpia jugis primariis 5 æqualibus, vittae parvae plurimae, carpophorum 2-fidum v. partitum, semen subteres facie planiusculum——Herbae perennes; folia pinnatisecta v. ternata serrata, umbellae multi-radiatae, involucri et involucelli foliola nulla v. pauca; flores albi.

1. **Pimpinella calycina** Maxim. in Mel. biol. IX. p. 184; Fr. et Sav. Enum. Pl. Jap. I.p. 182.

Herba perennis glabra, caule erecto 1—2 pedali subramoso; foliis radicalibus longe-petiolatis bi-ternatisectis, segmentis oblongis v. cuneato-ovatis v. rhombeo-oblongis serratis; foliis superioribus trisectis, segmentis oblongis v. ovato-lanceolatis c. 10—15 cm. longis 4—2 cm. latis acuminatis grosse serratis petiolis gramineis, laciniis omnibus foliorum membranaceis, ad margines et reticulas scabro-pilosis; petiolis sursum pilosis, vaginis attenuatis v. plus minus angulatis; involucris pauciphyllis brevibus linearibus; umbellis 8—10-radiatis, 3—5 cm. longis summo pilosis; involucelli phyllis circa 4—6 brevibus setosis; umbellulis multi-vulgo 15-floris; calycis dentibus lanceolatis acutis; petalis albis ovatis involutis staminibus petalis duplo longioribus patentibus; antheris brevi-oblongis badio-rubris; stylis brevibus dein elongatis; fructibus ovato-oblongis glabris multivittatis.

Nom. Jap. Kanotsumesō, Dakezeri.

Icon. Jap. Honzōzufu IX. fol. 10; Sōmokuzusetsu V, fol. 27.

Hab. In umbrosis nemoralibus Japoniae. Mense Augusto fl., Octobri fr. mat.

Hokkaido (Yezo,—Prov. Hidaka: Saruru (Y. Tokubuchi); Prov. Iburi: Muroran (J. Matsumura); Prov. Ishikari: Yūbari; Prov. Iburi: in monte Eniwa (Herb. Kawakami).

Honshiu—Prov. Mutsu: Aomori (Augusto fl.); Prov. Rikuzen: Sendai (Herb. Yasuda), Aone (ipse Auguto fl.); Prov. Iwashiro: Yumoto in tractu Aizu (Augusto. fl. R. Yatabe); Nakanosawa in Yamagōri (K. Nemoto); Prov. Shimotsuke: in alpibus Nikkō (Augusto—Octobri); Prov. Shinano: Fukushima in radice montis Komagatake (Augusto. R. Yatabe et J. Matsumura); Prov. Musashi: circa Tokyo et in montibus Mitake, Kobotoke (ipse); Prov. Kai: in monte Misakatoge; Prov. Suruga: in monte Fuji.

Kinshiu—Prov. Hizen: Nagayama in Sinum Simabarae; Kundshō-san (sec. Maxim.)

Observ. Plantae quae in humidis montanis crescunt variant foliolis minoribus tenuioribus profunde serratis pubescentibus.

2. **P. serra** Fr. et Sav. Enum. Pl. II. p. 372.

Perennis, caule erecto fistuloso 30—100 cm. alto glabro striato tereti subramoso; foliis longe petiolatis trisectis, segmentis subsessilibus terminalibus saepe petiolatis trisectis v. trifidis, lobis omnibus oblongis lanceolatis v. ovatis apice acuminatis basi rotundatis v. attenuatis margine æqualiter serratis albo-chartaceis; involucro nullo v. 1-phyllo setaceo; umbellis pauci-(4—5)-radiatis, radiis inæqualibus; involucellis sub-pentaphyllis setaceis inæqualibus; umbellulis 4—6-floris, pedicellis 7—8 mm. longis, petalis albis late ovatis apice acutis, filamentis petalis subæqualibus antheris albis, stylopodio conico depresso, stylis brevibus post anthesin elongatis; fructibus ovatis, valleculis trivittatis.

Nom. Jap. Tani-mitsuba, Kisomukago.

Hab. Prov. Iwaki, prope Taira (K. Okada); Prov. Shimotsuke: in alpibus Nikkō (Augusto. 1884); Prov. Shinano: in fissuris montis Asama (ipse), in humidis umbrosis montis Wadatoge (ipse); Prov. Kai: Kawaguchi. (coll. ign.)

3. **P. diversifolia** DC. Prodr. IV. p. 122; Clarke in Hook. f. Fl. Br. Ind. II. p. 688; Forbes et Hemsl. Ind. Fl. Sin. I. p. 329; Diels, Fl. Centr. China. P. 496.

P. sinica Hance in Journ. Bot. 1868. p. 113; Maxim in Mel. Biol. IX. p. 185; Franch. et Sav. Enum. Pl. Jap. I. p. 182.

Platyraphe japonica Miq. Prol. Fl. Jap. p. 245.

Planta dense pubescens v. subtomentosa; caule sulcato 2—3-pedali; foliis inferioribus longe-petiolatis late ovato-cordatis serratis, caulinis mediis et superioribus tri-sectis, segmentis petiolulatis v. sessilibus, valde variabilis, ovatis v. rhombeo-oblongis basi rotundatis cordatis v. cuneatis interdum lanceolatis augustis profunde pinnatifidis inciso-dentatis, dentibus mucronatis, laciniis rarius linearibus; foliolis omnibus supra scabriusculis subtus ad nervos pubescentibus; involucelli phyllis 1—4, umbellulis florentibus vix brevioribus; umbellulis 10—15-floris, pedicellis 1/2 cm. longis, petalis albis ovatis acumine inflexis, filamentis petalis longioribus, stylis brevissimis, stylopodio subdepresso, fructibus ovato-globosis, valleculis multi-vittatis.

Nom. Jap. Mitsubagusa.

Icon. Jap. Sōmoku-zusetsu. V. fol. 32. recto; Shitsumon-Honzō-gaihen, I. fol. 9.

Hab. Nippon media, prope Yokosuka (Sec. Fr. et Sav.)
Kiushiu—Prov. Bungo (Septembri fl!); Prov. Chikuzen: Kuhara (K. Nagano), in monte Oyasumi (K. Nagano); in monte Hōmandake (K. Nagano ex Herb. Makino); Prov. Hizen: ad montem Tarayama in Shimabara (sec. Maxim.) Prov. Higo: in valle montis Mamiwara (sec. Franch.), in monte Aso (ipse); Prov. Hiuga: in ignivomo Kirishima; Prov. Osumi (Herb. Mus. Imp.).

Distrib. China: Hupeh, Kwangtung; India boreali.

P. magna L. Fr. et Sav. Enum. Pl. I. p. 181.

Kiushiu—In fruticetis herbosis; in monte Kundshozan (Herb. Sav. no. 6)

Nothosmyrnium Miq.

Miq. Ann. Mus. Bot. Lugd. Batav. III. P. 58; Baillon Hist. d. Pl. p. 229; Drude in Nat. Pfl. Fam. III. abt VIII. p. 166 (adnot).

Calycis limbus obsoletus; petala obovata uninervia apice plana v. leviter involuta; stylus brevis, stylopodio crasso brevi conico instructis; fructus didymus basi emarginatus ovato-globosus ad commissuram valde constrictus; mericarpia juga tenera filiformia nec conspicua globosa a dorso leviter compressa; vittae valleculae multae superficiales; semen sectione subteres ad commissuram planiusculum nec involutum! Carpophorum bipartitum—Herbae perennes glabrae; folia bipinnatisecta oblongo-ovata, involucri et involucelli oligophylli; flores albi.

Nothosmyrnium japonicum Miq. Prol. Fl. Jap. p. 246; Franch. et Sav. Enum. Pl. Jap. I. p. 182; Franch. Pl. David. I. p. 140; Forbes et Hemsl. Ind. Fl. Sin. I. p. 329.

Caule fistuloso sulcato ramoso subflexuoso c. 3-pedali viridi ad nodos purpureo glabro ramis innovantibus pubescentibus; foliis circumscriptione ovato-oblongis bi-pinnatisectis, foliolis infimis sub-petiolatis reliquis sessilibus, foliolis late-ovatis rhombeo-oblongisve acutis duplicato serratis subtus ad nervos pilosis; petiolis basi vaginatis, foliolis supremis ad vaginas reductis; involucris 3—4-phyllis membranaceis late lanceolatis acuminatis demum reflexis, radiis 10-multis, subaequilongis 3—4 cm. longis; involucellis 4—5-phyllis late oblongis v. lanceolatis acutis albis cum nervis viridibus reflexis; umbellulis multi (15)-floris, pedicellis filiformibus c. 1 cm. longis, calycis dentibus obsoletis, petalis albis obovatis uninerviis, staminibus petalis vix longioribus v. brevibus, stylis brevibus erectis, antheris albis oblongis, fructibus atro-viridibus, mericarpiis globosis, jugis fere nullis, valleculis multivittatis; seminibus sectione transversali subteretibus, commissuris planis v. convexis.

Nom. Jap. Kōhon, Kasamochi.

Icon. Jap. Kawi. I. fol. 5. sub. Kōhon; Honzōzufu. IX. fol. 6 et 7.

Hab. Prov. Musashi: in umbrosis humidis circa Tokyo; Prov. Tosa: Sakawa (T. Makino); Prov. Chikuzen: in pago Keigomura. (K. Nagano). Sept—Octobri fl. Novembri fr. mat! Introductum?

Distr. China: Kiangsi.

Sium L.

Linn. Gen. n. 348; Willd. Sp. Pl. p. 1431; DC. Prodr. IV. p. 124; Endl. Gen. Pl. I. p. 772; Benth. et Hook. I. p. 893; Baillon, Hist. d. Pl. VII. 212; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 197.

Calycis dentes acuti parvi; petala obcordata emarginata cum lacinula inflexa, styli brevi erecti v. reflexi, stylopodio depresso conico; fructus ovatus a latere compressus ad commissuram constrictus juga primaria prominula, vittae valleculae multae et irregulariter sparsae; semen facie planum carpophorum individum——Herbae perennes; folia pinnata v. decomposita, foliola dentata; umbellae compositae, involucra et involucella ∞; flores albi.

Sium Ninsi L. Cod. 2025; Maxim. in Mel. Biol. IX. p. 18; Fr. et Sav. Enum. Pl. Jap. I. p. 181.

Herba perennis, radice fasciculato-tuberosa; caule erecto glabro 2—4-pedali supra ramoso ex axillis bulbifero; foliis rigide pinnatisectis, segmentis ovatis lanceolatisve rarius linearibus subsessilibus serratis, petiolis in vaginas amplexicaules attenuatis; involucris 5 inaequalibus linearibus membranaceis unis reliquis longioribus; umbellis 5—7-radiatis inæqualibus; involucellis 5—7-foliolis lanceolato-linearibus umbellulis brevioribus; umbellulis multifloris, pedicellis fructibus multo longioribus, calycis dentibus distinctis, petalis albis; fructibus ovato-globosis a latere compressis.

Nom. Jap. Mukago-ninjin.

Icon. Jap. Sōmoku-zusetsu. V. fol. 28; Sitsumon-Honzō. IV. fol. 5; Somoku-keimōzufu. VIII. fol. 11 recto.

Hab. In Japonia media et australi. Prov. Rikuzen: in monte Dainenji juxta Sendai (ipse); Prov. Iwashiro: in tractu Aizu (Augusto fl.); Prov. Shimotsuke: in monte Nikkō; Prov. Shinano: in monte Shiojiri, in radice montis Asama (ipse); Prov. Musashi: in campis Toda, circa Tokyo (ipse); Prov. Shimōsa: in graminosis humidis Mamamura, (ipse. Initio septembri fl.); Prov. Ise: circa oppidulum Tsu (K. Tani); Prov. Yamato: loco non indicato (Herb. Mus. Imp.).

Kiusiu—Prov. Hizen: Takeo (Augusto fl.), in monte Nagayama (sec. Maxim); Prov. Chikuzen: in pago Ohnomura (K. Nagano). Niihara (K. Nagano).

2. **S. nipponicum** Maxim. Mel. biol. IX. p. 17; Fr. et Sav. Enum. Pl. Jap. I. p. 187.

Caule sulcato ramoso erecto, foliis glabris pinnatisectis segmentis oblongis apice acutis, terminalibus saepe trilobis inæqualiter serratis, segmentis foliorum superioribus anguste lanceolatis, serraturis acutis; involucris 5—6-phyllis lanceolatis umbellis 8—10-radiatis inæqualibus; involucelli bracteolis 5—6-lanceolatis integris reflexis; umbellulis multifloris; calycis dentibus ovatis persistentibus, petalis albis ovatis cum lacinula inflexa; fructibus ovatis, valleculis 1—3-vittatis inaequalibus, commissuris multivittatis.

Nom. Jap. Sawazeri, Numazeri.

Icon. Jap. Somoku-zusetsu, V. fol. 20 recto.

Hab. In fossis et paludosis Japoniae borealis et mediae. Augusto-Septembri fl! Prov. Iwashiro: in tractu Aizu; Prov. Shimōsa: Mama juxta Tokyo; Prov. Musashi: circa Tokyo (ipse).

Shikoku—Prov. Tosa: Tosagōri.

Var. ovatum (Yatabe) m.

Sium ovatum Yatabe. in Bot. Mag. Tokyo. V. no. 49 p. 73.

Foliis glabris pinnatis, segmentis foliorum inferioribus sessilibus ovatis v. oblongo-ovatis, terminalibus saepe ovato-orbiculatis basi

rotundatis cordatisve argute serratis 3—10 cm. longis 3—5 cm. latis; segmentis reliquis ovatis lanceolatis v. oblongo-linearibus. mericarpiis unis saepe abortis.

Nom. Jap.: *Hiroha-numazeri.*

Hab. Prov. Musashi: in orizetis ad fossis Omiya circa Tokyo (Septembri fl. ipse), Shirako (T. Makino); Prov. Shimōsa: Sakura (Herb. Makino): Prov. Sanuki in ins. Shikoku: Tadotsu (T. Makino).

Oenanthe L.

Linn. Gen. n. 352; Hoffm. Umbellif. I. p. 73: DC. Prodr. IV. p. 136; Endl. Gen. Pl. II. p. 773; Benth. et Hook. Gen. Pl. I. p. 905; Baillon, Hist. d. Pl. VII. p. 213: Drude in Nat. Pfl. Fam. III. abt VIII. p. 204.

Calycis dentes 5 lanceolati persistentes; petala obovata emarginata cum lacinula inflexa; stylopodium conicum; fructus cylindricus stylis strictis coronatus; mericarpia 5-juga, jugis obtusis crassis subaequalibus corticosis, valleculae 1-vittatae commissura 2-vittata. carpophorum indistinctum—Herbae perennes, umbella composita, involucrum saepe nullum, involucelli bractae polyphyllae; flores albi.

1. **Oenanthe stolonifera** DC. Prodr. IV. p. 138: Wight, Illust. Ind. Bot. v. 571; Ic. Pl. Ind. Or. t. 571; Hance in Journ. Linn. Soc. XVIII. p. 81 et Journ. Bot. 1878 p. 228; C.B. Clarke in Hook. f. Fl. Br. Ind. II p. 696; Franch. Pl. David. I. p. 140; Maxim. in Engl. Bot. Jahrb. VI. p. 61; Franch. et Sav. Enum. Pl. Jap. I. p. 185; Forbes et Hemsl. Ind. Fl. Sin. I. p. 331; Henry, List Pl. Form. in Tr. As. Soc. Jap. vol. XXIV. suppl. p. 47; Hemsl. et Coll. Journ. Linn. Soc. XXVIII. p. 61; Kanitz, Die Result. Bot. Samml. in Wiss. Ergeb. d. Reise d. Graf. B. Szechenyi in Ost. Asi. Bd. II. p. 701; Itō et Matsumura, Tent. Fl. Lutch. I. p. 269; Diel, Fl. Centr. China in Eng. Bot. Jahrb. XXIX. P. 498.

Oen. javanica DC. Prodr. IV. p. 130; Miq. Cat. Fl. Jap. p. 41; Fr. v. Muller. Fragm. Phytogr. Austr. V. p. 182; Zolling. Syst. Verz. Ind. Arch. sam. Jap. empf. Pfl. II. p. 189.

Dasyloma subbipinnatum Miq. Prol. Fl. Jap. p. 247.

D. javanicum Miq. Fl. Ind. Bat. I. pt. 1. p. 41.

Phellandrium stoloniferum Roxb. Fl. Ind. II. p. 93.

Sium decumbens Buerg. ex Miq. Prol.

Herba erecta glabra interdum semi-decumbens; caule fistuloso-striato 1-pedali; foliis inferioribus bi-pinnatisectis, segmentis ultimis lanceolatis vel rhombeo-oblongis basi cuneatis apicè acutis petiolulatis sessilibusve inciso—serratis; umbellis oppositifoliis, involucris 2—3-phyllis lanceolato-linearibus v. nullis; umbellis 6—12-radiatis; involucellis oligophyllis lineari-acuminatis interdum umbellulis longioribus; umbellulis plurifloris, floribus masculis hermaphroditis intermixtis; calycis dentibus lanceolatis, petalis albis obovatis, stylis elongatis reflexis, fructibus ellipsoideis jugis crassissimis. carpophoris individis.

Nom. Jap. Seri, Shiriba (Nom. Liuk. sec. Ito).

Icon. Jap. Sōmoku-zusetsu. V. fol. 19; Hozōzufu. XLVII. fol. 11. sub. Suikin.

Hab. In orizetis per totam Japoniam. Augusto fl! Saepe culta!

Hokkaidō (Yezo)—Prov. Iburi: Mororan (J. Matsumura), Oshamambe (Herb. Kawakami); Prov. Ishikari: Sorachibuto (Herb. Kawakami); Prov. Oshima. Hakodate (Herb. Mus. Imp).

Kurile—Yetorofu. (T. Kawakami Cult!).

Honshiu—Prov. Mutsu: Kuniyoshi in tractu Tsugaru: Prov. Rikuzen: circa urbem Sendai (A. Yasuda): Prov. Iwashiro: Wakamatsu et Motomiya (K. Nemoto): Prov. Shimotsuke: in monte Nikkō; Prov. Shinano: Fukushima (Herb. Mus. Imp.); Prov. Echigo: Takahata (K. Yendō); Prov. Musashi: circa Tokyo (Ipse. Augusto fl. et fr!); Prov. Ise: Otobemura circa oppidulum Tsu (K. Tani); Prov. Omi: in monte Ibukiyama (K. Tsuzi): Prov. Kawachi: in monte Kongōsan (T. Tada no. 115.): Prov. Harima: in pago Kashima (U. Ogami).

Shikoku—Prov Tosa.

Kiushiu—Prov. Chikuzen: in monte Wakasugiyama (K. Nagano): Prov. Hizen: circa Nagasaki (Maxim): Prov. Higo: circa Kumamoto (ipse): Ins. Tsushima (ipse).

var japonica Maxim. Fr. et. Sav. Enum. Pl. Jap. I. p. 185.

Dasyloma japonica Miq. Prol. Fl. Jap. p. 247.

Oenanthe laciniata Zoll. Syst Verz. p. 139; Miq. Cat. Fl. Jap. p. 141.

Segmentis foliorum subovatis acutis inciso-serratis, serraturis passim duplicatis sed sublobuliformibus, involucellis oligophyllis umbellulis parum brevioribus.

Nom. Jap. Seri. Shiriba (Nom. Liukiu. sec. Itō).

Hab. Kiushiu—circa Nagasaki (Maxim. sec Fr. et Sav.)
Liukiu—Ins. Okinawa (Utchina) (A. Tashiro!), in oppido Nafa et Idzunzatchi (Yamada!); in tractu Kundjan ad Kushimajiri (S. Tanaka), ad Mutubu (S. Tanaka): Archipel. Yayeyama (Yema): Ins. Ishigaki, ad pagum Naramura (T. Itō).
Formosa—Tamsui (Oldham ex Hemsl).

Distr. China: Chihli, Kiansu, Hanchow (C. Owatari); India orientali; Java.

2. **Oen. benghalensis** Benth. et Hook. Gen. Pl. I. p. 906; C.B. Clarke in Hook. Fl. Br. Ind. II. p. 696; Forbes et Hemsl. Ind. Fl. Sin. I. p. 331; Henry in Tr. As. Soc. Jap. XXIV. suppl. p. 47: Itō et Matsumura, Tentam. Pl. Lutch. I. p. 263.

Dasyloma benghalense DC. Prodr. IV. p. 140; Wight, Illust. Ind. Bot. et Ic. Fl. Ind. Or. t. 568.

Dasyloma glauca DC. Prodr. IV. p. 140; Hook. et Arn. Bot. Beech. Voy. p. 264.

Seseli benghalensis Roxb. Fl. Ind. II. p. 94.

Caule erecto simplici vel subramoso striato glabro 30 cm. alto; foliis circumscriptione deltoideis pinnatisectis; segmentis infimis

pinnatisectis summis pinnatifidis v. trifidis ; lobis ultimis oblongis v. oblongo-cuneatis simplicibus vel pinnatifidis crenatis ; petiolis basi vaginantibus, margine membranaceis ; umbellis axillaribus compositis 5—6-radiatis confertis ; involucris nullis, involucellis setaceis oligophyllis parvis ; pedunculis brevibus, umbellulis 10—12-floris, pedicellis brevissimis ; calycis dentibus setaceis, petalis albis obovatis inflexo-acuminatis, staminibus petalis longioribus, stylis brevibus, stylopodio conico ; fructibus oblongo-cylindraceis, jugis corticosis vittis valleculae solitariis commissurae 2.

Hab. In Formosa boreali : Taipe (C. Owatari) ; Tamsui (sec. Henry). Liukiu et Bonin (sec. Hook. et Arn.)

Distr. China : Kwangtung ; India orientali.

3. **Oen. linearis** Wall? DC. Prodr. IV p. 138 ; C.B. Clarke in Fl. Br. Ind. II p. 696 ; Franch. Not. sur Quelq. Ombel. Yunnan, Extra. du Bul. Soc. Philom. Paris 1894. p. 26.

Caule erecto glabro sulcato ramis axillaribus ; foliis radicalibus... .... superioribus 3—4-jugato-bipinnatisectis, jugis primariis infimis petiolatis, segmentis ultimis lineari-lanceolatis integris 3—4 mm. latis 7—8 cm. longis subtus glaucescentibus ; petiolis basi vaginatis margine membranaceis ; umbellis oppositifoliis 8—9-radiatis inaequalibus ; involucris nullis, involucellis 5—6-foliolis lanceolato-linearibus radiolis brevioribus ; umbellulis multi-floris, calycis lobis prominulis acutis, petalis albis obovatis apice acuminatis cum lacinulis inflexis ; staminibus petalis longioribus antheris albis, stylis petalis subæquilongis erectis vel vix divergentibus, stylopodio conico margine integro ; fructibus...............

Nom. Formos. Shuitenhon (fide Y. Satake).

Hab. Formosa—Taichu (Y. Satake).

Distr. India : Nepal ; China : Yunnan.

Seseli L.

Linn. Gen. n. 360; DC. Prodr. IV. p. 144; Endl. Gen. Pl. II. p. 771; Benth. et Hook. I. p. 901; Baillon, Hist. d. Pl. VII. p. 217; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 201—Libanotis DC. l.c. p. 150.

Calycis margo 5-dentatus, dentibus obtusis prominulis v. minutis, petala lata valde inflexa cordata v. late elliptica; stylopodio late depresso v. conico, stylis brevibus deflexis; fructus ovatus v. obovatus, mericarpia jugis primariis vix prominulis lateralibus vix majoribus, vittae ad valleculas solitariae v. 2, carpophorum individuum; semen transverse 5-gonum facie planiusculum——Herbae perennes erectae; folia 3-multi-pinnata; umbella multi-radiata, involucra pauca v. 0; involucella ∞; flores albi.

1. **Seseli Libanotis** Koch. Gen. Trib. Pl. Umb. p. 111; Sow. Engl. Bot. p. 138; Fr. et Sav. Enum. Pl. Jap. I. p. 183; Franch. Pl. David. I. p. 140; Hemsl. et Forbes. Ind. Fl. Sin. I. p. 330.

Libanotis vulgaris DC. Prodr. IV. p. 150.

Libanotis montana All. Ledeb. Fl. Ross. II. p. 279.

Athamanta Libanotis L. Sp. 351; Willd. Sp. Pl. p. 1400.

Herba perennis, caule erecto cavo stramineo ramoso scabro-pubescenti, foliis bipinnatisectis segmentis oblongis v. ovatis inciso-pinnatifidis; petiolis pubescentibus plus minus vaginatis, laciniis lanceolatis supra setulosis; involucris nullis v. 1-phyllis linearibus; umbellis terminalibus oppositifoliis multiradiatis radiis intus scabro-puberulis; involucellis pauciphyllis linearibus inæqualibus; umbellulis multifloris, calycis margine 5-dentato, petalis albis

ovatis inflexo-acuminatis, staminibus petalis duplo longioribus, stylopodio depresso, stylis brevibus ; fructibus ovato-oblongis.

Nom. Jap. Ibuki-bōfu.

Icon. Jap. Honzozufu, VII. fol. 15 ; Somokuzusetsu, V. fol. 12.

Hab. Hokkaidō—Prov. Hidaka : Samani sandō* (Augusto. fl. R. Yatabe) ; Prov. Iburi : Yubutsu (Augusto R. Yatabe) ; Prov. Oshima : Fukuyama (T. Kawakami).
Honshiu—Prov. Mutsu : Aomori, Ajigasawa in tractu Tsugaru (Augusto 1880) ; Prov. Rikuzen : Aone (ipse) ; Prov. Iwashiro : in tractu Aizu* (Yatabe) in Campis Iwase (ipse), in pago Moniwa (Herb. Makino) ; Prov. Hitachi ; Prov. Shinano : ad radicem montis Komagatake,* loco non commemorato (D. Takashima) ; Prov. Kazusa ; Ichinomiya ; Prov. Musashi : in montibus Chichibu ; circa Tokyo ; Prov. Sagami : Uraga (ipse) ; Prov. Ise : loco non indicato (T. Tani) ; Prov. Sestu : in monte Nidosan.

Distr. In Rossia, Europa.

var. daucifolia (DC.) Fr. et Sav. Enum. Pl. Jap. I. p. 184.

Libanotis vulgaris DC. *var. daucifolia* DC. Prodr. IV. p. 150.

Caule augulato, foliis bipinnatisectis, segmentis foliorum augustis lineari-lanceolatis acutis ; ceteris typicae similis.

Nom. Jap. Kobano-Ibukibōfu.

Hab. Prov. Shinano : in monte Asama (ipse), in monte Wadatōge (ipse) ; Prov. Iwashiro : in tractu Aizu ; Prov. Ohmi : in monte Ibukiyama (K. Tani, K. Tsuji, T. Makino).

Distr. Sibiria et in montibus Europae.

2. **Seseli Tachiroei** Fr. et Sav. Enum. Pl. Jap. II. p. 375.

Hab. in monte Asamayama, Prov. Kotsuke Nobis ignota !

Fæniculum Adans.

Fæniculum vulgare Gaertn.

* Forma Sibirica, foliis subtus glaucescentibus !

Nom Jap. Kwaikō, Kureno-omo, Uikyō

In hortis japonensibus saepe cultum. Liukiu:—Ins. Okinawa: in oppidum Nafa. (cult. Herb. Mus. Imp.). Ins. Bonin (cult. Herb. Makino.)

Anethum L.

Anethum graveolens L. *Nom. Jap.* Inondo. Rarius cult.

Cnidium Cusson.

"Cusson. Mem. Soc. Med. Par. 1782 p. 282"; Hoffm. Umbellif. I. p. 157; DC. Prodr. IV. p. 152; Endl. Gen. Pl. II. p. 775; Benth. et Hook. Gen. Pl. I. p. 914 (sub Selino); Baillon Hist. d. Pl. VII. p. 210 (sub Meo); Drude in Nat. Pfl. Fam III. abt. VIII. p. 210.

Calycis margo obsoletus v. parvus, petala obovata emarginata cum lacinula inflexa, stylopodium conicum stylis reflexis; fructus ovatus, subrotundatus, a latere vix compressus, mericarpia jugis 5 aequalibus crassis lateralibus marginantia; vittae valleculae solitariae parvae, commissurae 2—4; semen semiteres facie planum.——Herbae biennes v. perennes, folia bi-tripinnatisecta, segmentis lanceolatis, umbella multiradiata; involucra nulla, involucella polyphylla: flores albi.

1. **Cnidium japonicum** Miq. Prol. Fl. Jap. p. 248.
Selinum japonicum Fr. et Sav. Enum Pl. Jap. I. p. 186.

Perenne, caule decumbente 20—30 cm. alto ramoso glabro striato, ramis axillaribus; foliis glabris nitidulis inferioribus longe, superioribus brevi-petiolatis pinnatisectis 3—4-jugis pinnis termin-

alibus late ellipticis cuneatis trifidis, reliquis pinnatilobis, lobis apice obtusis mucronulatis basi plus minus cuneatis; petiolis basi vaginis membranaceis dilatatis; umbellis oppositifoliis; involucris 5—6-phyllis inaequalibus lineari-setaceis membranaceis, pedicellis 5—6 brevibus; involucelli bracteolis 3—5 brevibus linearibus acuminatis; umbellulis 3—5-pluri-radiatis, pedicellis brevibus 1—2 mm. longis, petalis albis obovatis apice in acumen inflexis, calycis dentibus obsoletis, antheris purpureis, fructibus 2—4 mm. longis ellipticis subteretibus, jugis primariis latis, carpophoris bi-partitis.

Nom. Jap. Hama-zeri.

Icon. Jap. Somoku-zusetsu. V. fol. 34; Honzōzufu, IX. fol. 5 recto sub Jashōshi.

Hab. Prov. Mutsu: in arenosis maritimis Asamushi (Herb. Yasuda); Prov. Rikuzen: Ōkawamura in Momonōgori (ipse). Shōbuta (Herb. Yasuda); Prov. Iwaki: Yatsukura (K. Nemoto. Octobri 1895. fr!); Prov. Kazusa: in promontrium Daitō; Prov. Musashi: circa Tokyo (Julio—Octobri fl. et fr!); Prov. Sagami: Misaki (ipse. julio fl.); Prov. Tajima: Tsuiyama (Herb. Mus. Imp). Kiushiu—Prov. Chikuzen: in promontrium Najima (K. Nagano); Prov. Hizen: Nagasaki (Maxim); Ins. Tsushima (ipse!).

Distr. Korea.

2. Cn. longeradiatum (Maxim).

Selinum longeradiatum Maxim. in Mel. Biol. XII. p. 469.

Caule erecto glabro subramoso; petiolis foliorum oblongis latis membranaceis apice bi-auriculatis, vaginiis superioribus ovatis; laminis trisectis, segmentis bipinnatisectis obovatis 3—5-pinnatifidis glabris, lacinulis oblongis apice acutis; involucris nullis vel 1-phyllis, umbellis circiter 20-radiatis, radiis inæqualibus 1-pollicaribus intus puberulis; involucellis 7—10 phyllis lineari-lanceolatis uninerviis margine membranaceis umbellulam parum superantibus; umbellulis multifloris, calycis dentibus obtusis, petalis albis oblongis apice obtusis nec emarginatis; filamentis petalis æquilongis antheris atropurpureis, fructibus

late ovalibus jugis obtusis lateralibus alatis duplo latioribus, valleculis 1—, commissura 2-vittatis.

Icon Jap. Shitsumon-honzō. I. fol. 3. sub. Yamaseri?

Hab. Kiusiu—In monte Naga (Sec. Maxim): Prov. Ōsumi: ad vulcanum Sakurajima (S. Ikeno 22. Augusto 1894 fl.): Prov. Higo: in vulcano Aso, (ipse. Augusto 1901. fr.)
Honshiu—Prov. Ise: Shirakawa (S. Okubo).

3. **Cn. ajanense** Drude. in Nat. Pfl. Fam. III. abt. VIII. p. 210.

Tilingia ajanensis Regel et Tiling. Fl. Ajan. n. 132; Maxim. Prim. Fl. Amur. p. 30; Fr. Schmidt. Fl. Ins. Sach. p. 45 et 135.

Selinum Tilingia Maxim. Mel. biol. XII. p.469.

Caule gracili 1—2-pedali glabro; foliis glabris radicalibus bipinnatisectis, segmentis distincte petiolulatis circumscriptione oblongis v. ovatis pinnatipartitis; partionibus sessilibus vel brevipetiolulatis profunde pinnatifidis partitisve, laciniis oblongis obovatis vel cuneatis interdum lanceolatis inciso-serratis, serraturis apiculatis; petiolis basin versus vaginis dilatatis amplexicaulibus; vaginis superiorum oblongis margine membranaceis foliis microphyllis aut in setas reductis; involucris 2—3-phyllis vel nullis subulato-lanceolatis; umbellis 10—12-radiatis, radiis subæqualibus; involucellis 7—10 linearibus lanceolatis umbellulis vix brevioribus; umbellulis multifloris, calycis dentibus parvis distinctis, petalis albis oblongis cum lacinulis inflexis, antheris violaceis, stylopodio depresso; fructibus oblongo-ovatis pedicellis aequalibus, v. brevioribus, jugis dorsalibus semi-alatis, marginalibus alatis, valleculis dorsalibus 1—, lateralibus 2—, commissaralibus 4-vittatis.

Nom. Jap. Chishima-ninjin (sec. K. Miyabe in Bot. Mag. Tokyo vol. VIII. p. 483).

Hab. Kurile—Ins. Urup: Auauma (K. Jimbo in Herb. Colleg. Agric. Sapporo).

Megane (T. Kitahara); Ins. Etrofu (Etrup): Onnebetsu (T. Ishikawa in Herb. l.c.): Moyoroyama (S. Yokoyama in l.c.): Shikotan (K. Miyabe in l.c.); Shinshiri (Kodama).

Hokkaido (Yezo)—Prov. Kushiro: in monte Meakan (K. Fujita T. Kawakami); Prov. Kitami: ins. Rishiri (Hirose): Ins. Repunshiri (S. Hori): Prov. Ishikari: in monte Yūbari (T. Ishikawa).

Honshiu—Prov. Mutsu: in monte Iwakiyama (Julio. fl.), in summitate montis Hakkōdayama (S. Konishi ex K. Nagano); Prov. Rikuchū: in monte Iwateyama (K. Miyabe et Y. Takahashi), in tractu Nambu (sec. Maxim), in monte Kurikoma; Prov. Rikuzen: in monte Kattadake (S. Kusano, K. Nemoto; A. Yasuda; Sato et ipse): Prov. Ugo. in monte Chōkaizan; Prov. Shinano: in alpibus Komagatake et Shirouma (ipse).

Distr. Sibiria orientali. Amur. Sachalin.

4. **Cn. formosanum** m. Herba perennis radice fibroso, caule humile 10—20 cm. alto ramoso striato v. sulcato; foliis teneris plerumque radicalibus fasciculatis longe petiolatis, caulinis brevipetiolatis, circumscriptione elongato-ovatis 1—2-pinnatisectis, foliolis 1—2-pinnatifidis, segmentis ultimis oblongo-linearibus apice mucronatis; petiolis glabris basi dilatatis amplexicaulibus extus puberulis; umbellis terminalibus compositis multiradiatis inæqualibus; involucris 5-phyllis linearibus margine integris radiis æquilongis; involucellis linearibus uninerviis pedicellos æquantibus, ramis juvenilibus involucellisque puberulis; umbellulis multi-floris, pedicellis inæquilongis, 2—3 mm. longis, calycis margine obsoleto, petalis albis ellipticis inflexo-acuminatis, filamentis petalis æquilongis, antheris albis, stylis reflexis, stylopodio brevi-conico, fructibus oblongis sectione transversali subteretibus, mericarpiis jugis primariis prominulis, omnibus subæqualibus semialatis, valleculis 1 commissuris 2-vittatis, semine facie planiusculo, carpophoris bi-partitis.

Nom. Jap. Kagi-noninjin (A. Tashiro in sched.); *Liumintsō* (Nom. Formos. fide Satake).

Hab. Formosa: in campis apricis vulgare in Kagi et Tainan. (A. Tashiro. no. 35! A Martio 1897. fl. et fr. mat!); circa oppidum Taichū Formosae mediae (Y. Satake, no. 9. Februario 1899. fl. fr!)

Herba ramossisima vix $\frac{1}{2}$-pedalis, folia 5—10 cm. longa; pedicellus 6—7 mm.; fructus 5—6 mm. longus. Habitu et forma foliorum ad Aethusam Cynapium accedere videtur, sed differt petalis æqualibus nec inaequalibus et fructibus oblongis nec ovatis, jugis prominulis, involucellis foliolis brevioribus, stylopodio distinctiori. Haec species Selino dissecto (DC). Clarke (Fl. Br. Ind. II. p.701) ex descriptione optime affinis videtur.

Ligusticum L.

Linn. Gen. n. 346; Willd. Sp. Pl. 1424; DC. Prodr. IV. p. 157; Endl. Gen. Pl. II. p. 776; Benth. et Hook. Gen. Pl. p. 911; Baillon Hist. d. Pl. VII. p. 210; Drude in Nat. Pfl. Fam. III abt. VIII. p. 211.

Calycis margo obsoletus v. dentatus; petala obovata v. obcordata acumine inflexa v. 2—loba; stylopodia crassa, stylis elongatis reflexis; fructus ovatus v. oblongus transverse subteres; mericarpia 5-juga, jugis primariis prominulis v. alatis; vittae ad valleculas pluriae; semen a dorso compressum, sectione 5-gonum, facie planum; carpophorum bipartitum.——Herbae perennes, caulis elatus v. humilis ramosus, folia ternato-pinnata vel pinnatim decomposita; umbellae multiradiatae, involucra nulla v. multiphylla, involucelli bracteolae multae; flores albi.

Ligusticum scoticum L. Sp. 359; Willd. Sp. Pl. p. 1424; Aiton, Hortus Kew. II. p. 141; Spr. Syst. Veg. I. p. 907; DC. Prodr. IV. p. 157; Loureiro, Fl. Cochinch. ed. Willd. I. p. 224; Sow. Engl. Bot. 1207; Hook. et Arnot. Bot. Beech. Voy. p. 115 et 125; Hook. Fl. Bor. Americ. I. p. 265; Ledeb. Fl. Ross. II. p. 286;

Regel et Til. Fl. Ajan. n. 133 ; Ruprecht, Rev. Umb. Kamtsch. p. 23. § 6 ; Sieb. et Zucc. Fam. Nat. n. 427 ; Maxim. in Mel. Biol. IX. p. 249 ; Fr. et Sav. Enum. Pl. Jap. I. p. 190 et II. p. 374 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 332 (in Nota) ; Coult. et Rose, Rev. N. Am. Umb. 1888 p. 85 ; Miyabe, Fl. Kurile Isl. in Mem. Bost. Soc. Nat. Hist. IV. no. VII. p. 236 ; Britton et Brown, Ill. Fl. Canad. II. p. 519 ; Kuroz. Fl. Chilcat. S. Alask. in Engl. Bot. jahrb. XIX. p. 582.

Angelica scotica Lam. Encycl. I. p. 173.

Apium ternatum Spr. Syst. Veget. I. p. 890.

Haloscias scoticum Fries. Maxim. Prim. Fl. Amur. p. 127 ; Fr. Schmidt. Reis. Amur. Ins. Sach. p. 135.

Angelica foliolis tripartitis, lobis superne incisis, obtusis.............. Gmel Fl. Sibi. I. p. 193. no. 9.

Caule erecto glabro 2—3-pedali subramoso ; foliis biternatisectis, segmentis primariis petiolatis, secundariis brevi-petiolulatis v. sessilibus, segmentis omnibus late rhombeo-orbiculatis cuneatis trifidis, laciniis grosse dentatis glabris ; petiolis basi dilatatis, vaginiis foliorum superiorum ampliatis marginibus membranaceis subauriculatis ; involucris 5—8-phyllis lanceolato-linearibus inæquilongis, umbellis 14—15-radiatis, radiis inæqualibus ; involucelli foliolis 5—6 lanceolato—linearibus pedicellis subæqualibus v. brevioribus rarius longioribus ; umbellulis 20-multifloris, pedicellis 9—10 mm. longis, calycis dentibus triangularibus minutis, petalis obovatis acutis involutis ad costam plus minus constrictis, stylis expansis, stylopodio conico ; fructibus c. 11 mm. longis 3 mm. latis oblongo-cylindricis, mericarpiis 5-jugis prominulis subæqualibus, lateralibus marginantibus, valleculis 3-vittatis, commissuris latis 8-vittatis ; seminibus facie subteretibus convexis.

Forma Chromocarpiae valde variabilis, nunc elongata, jugis subæqualibus, nunc lata jugis tribus dorsalibus vix prominulis lateralibus in alas plus minus expansis. Folia item variabilia. alia argute profundeque alia leviter crenata.

Nom. Jap. Marubatōki.

Hab. In Japonia boreali. littoribus maritimis.

Kurile—Ins. Etorofu (Etrup); Tsurubetsu (ex Miyabe), Rubets (T. Kawakami); Ins. Shikotan (T. Kawakami).
Hokkaidō (Yezo)—Prov. Shiribeshi: Ins. Okushiri (K. Miyabe et Tokubuchi). Takashima (J. Matsumura); Prov. Iburi: Mororau (J. Matsumura. August. fr!), Oshamanbe (T. Kawakami); Prov, Oshima: circa Hakodate (R. Yatabe et J. Matsumura).
Honshiu—Prov. Rikuzen: in archip. Matsushima (T. Makino).

Distr. In Rossia arctica, Sibirica orientali. Kamtschatka; America arctica. in maritimis Scotiae.

2. **Ligusticum acutilobum** S. et Z. Fam. Nat. Fl. Jap. I. p. 203 n. 428; Maxim. in Mel Biol. IX. p. 247; Fr. et Sav. Enum. Pl. Jap. I. p. 186; Forbes et Hemsl. Ind. Fl. Sin. I. p. 332; Palibin. Consp. Fl. Kor. I. p. 97; A. Kanitz. Anthophyt. Jap. leg. p. 28; Henry. List. Pl. Form. p. 47?

Sium triternatum Miq. Prol. Fl. Jap. p. 245.

Apium ternatum Silb. Syn. Fl. œcon. n. 246.

Caule erecto 30—60 cm. alto ramoso striato purpureo sub umbella pubescenti; foliis biternatisectis membranaceis, segmentis rhombeo-oblongis glabris petiolatis trifidis, laciniis acutis inciso-dentatis. petiolis dilatatis vaginatis margine membranaceis; involucro 1-phyllo. phyllis linearibus subfoliaceis interdum 2—3-serratis; umbellis oppositifoliis multi—(circa 25)-radiatis, radiis inæqualibus intus scaberulis; involucelli phyllis 5—8 lanceolato—linearibus v. linearibus setaceis acutissimis pedicellos æquantibus plerumque superantibus; umbellulis multi-floris (30). pedicellis inæqualibus,

floribus fertilibus masculisque intermixtis ; calycis dentibus nullis v. subdeltoideis minutis, petalis albis oblongo-obovatis apice acutis lacinulis involutis, stylis diversis dein reflexis capitatis ; fructibus oblongis teretibus a dorso leviter compressis, mericarpiis jugis prominulis subæqualibus vittis ∞ ; seminibus facie convexis commissuris latis, carpophoris bipartitis.

Nom. Jap. Tōki.

Icon. Jap. Honzōzufu, IX. fol. I. verso et fol. 2 ; Somoku-zusetsu, V. fol. 5.

Hab. In Japonia septentrionali (praeter Hokkaidō) et media : in graminosis montanis. Augusto fl! Prov. Mutsu: Aomori; Prov. Rikuzen: ad ripas fluvii Kitakami; Prov. Ugo: in monte Chōkaizan; Prov. Shinano: loco non indicato (D. Takashima); Prov. Shimotsuke: in monte Nyobō prope Nikkō (ipse); Prov. Hitachi: in monte Tsukuba (T. Makino); Prov. Sagami: circa Yokosuka (Savatier); Prov. Kaga: in monte Hakusan: Prov. Ōmi: in monte Ibukiyama (Tani).
Formosa: Kelung (sec. Henry) non visum!

Distr. In archipel. Koreano.

Habitu sequenti valde affine, sed differt caule gracili foliis augustioribus argute serratis, nerviis acutis omnibus ad apices serraturarum terminatis.

3. **Lig. japonicum.** Maxim. in Mel. biol. IX p. 246 ; Fr. et Sav. Enum. Pl. Jap. II. p. 374.

Perenne, caule glabro sub umbella puberulo erecto 2—3-pedali striato ; foliis ternato pinnatisectis, segmentis oblongis vel ovato-lanceolatis vel circumscriptione rhombeis trifidis partitisve, lobis oblongo-lanceolatis margine serraturis subtilis acutis mucronulatis ; foliis summis ternatis, segmentis sessilibus terminalibus 3—, lateralibus 2-lobatis, lobis lanceolatis acutis vaginis summis ampliatis oblongis ; involcuris nullis vel 1-phyllis ; umbellis 30—60-radiatis 3—7 cm. longis sulcatis interne puberulis ; involucellis 5—6-phyllis lineari-

setaceis, floribus masculis 3—5 mm. longis, fructiferis circiter 1 cm. longis, calycis dentibus parvis, petalis obovatis acumine inflexis, staminibus petalis longioribus, stylis brevibus demum elongatis reflexis, stylopodio depresso; fructibus oblongis a dorso compressis, jugis lateralibus marginantibus, dorsalibus nerviformibus, valleculis saepe 3—, commissuris utrinque 3—4-vittatis.

Nom. Jap. Iwate-tōki, Nambu-tōki (sec. Miyabe in Bot. Mag. Tokyo VIII. p. 483).

Hab. Japonia borealis: in montibus altis.

Hokkaido (Yezo)—Prov. Hidaka: Shoya in Horoizumi (Tokubuchi), Samani (Augusto fl.)
Honshiu—Prov. Mutsu: in monte Iwakiyama (R. Yatabe); Prov. Rikuchū: in monte Iwateyama (K. Miyabe et A. Yasuda!); Prov. Echigo: loco non indicato; ad cacumine montis Shimizugoye (Herb. Makino).

4. **L.** (Angelica) **ibukiense** (T. Makino). Caule erecto glabro ramoso striato; foliis bi-ternatis v. bipinnatisectis, segmentis petiolatis ovatis trifidis v. partitis, partionibus rhombeo-oblongis inciso-crenatis apice mucronatis supra viridibus subtus glaucescentibus petiolis longis basin versus dilatatis, superioribus sessilibus vaginiis oblongis; involucris 1-phyllis setaceis; umbellis 10-radiatis, involucellis sub-7-phyllis lanceolato-linearibus umbellulis æqualibus v. longioribus interdum foliaceis 1-nervis; umbellulis c. 10-floris, calycis margine distincte setaceo, petalis albis ovatis ad apices valde inflexis raro obcordatis; staminibus petalis longioribus antheris albis, stylis erectis brevibus, stylopodio crasso pulvinato; fructibus oblongis nec dorso compressis, mericarpiis jugis 5 prominulis æqualibus, commissuris latis, sectionibus transversalibus, subteretibus, vittis ∞ ad semina adhærentibus, seminibus facie convexis vel planis, carpophoris bipartitis.

Angelica ibukiensis Makino in Sched.

Nom. Jap. Serimodoki.

Icon. Jap. Somokuzusetsu, V. fol. 24 et 25.

Hab. Prov. Omi : in monte Ibukiyama (T. Makino) 4. Novembri 1893. fr!

Coelopleurum Ledeb.

Ledeb. Fl. Ross. II. p. 361 ; Endl. Gen. Pl. Suppl. n. 4535 ; Drude. in Nat. Pfl. Fam. III. abt. VIII. p. 212.
Archangelica in Benth. et Hook. Gen. Pl. I. p. 1009.

Calycis limbus obsoletus, petala oblonga integra apice involuta ; fructus a dorso parum compressus, mericarpia 5-juga elevata crassa subcarinata exteriore corticosa, interiore arcte adnata ejugata, vittae numerosae, carpophorum bipartitum liberum, semen transverse semilunare ; herba perennis, flores albi.——A genere Angelicae differt fructibus a dorso minus compressis, vittis numerosis seminibus liberis.

Coelopleurum Gmelini Ledeb. Fl. Ross. II. p. 361 ; Ruprecht, Rev. Umb. Kamtsch. p. 12 ; A. Gray. Bot. Jap. p. 391 ; Fr. Schmidt, Fl. Sachal. 136 ; Coult. et Rose. Rev. N. Am. Umb. p. 60 ; K. Miyabe, Fl. Kurile Isl. p. 236.

Archangelica Gmelini DC. Prodr. IV. p. 170 ; Hook. Fl. Bor. Am. I. p. 267 ; Benth. et Hook. Gen. Pl. I. p. 1009 ; Fr. et Sav. Enum. Pl. Jap. I. p, 188 ; Kurtz. Fl. Chilcat. Alask. in Engl. Bot. jahrb. XIX. p. 382 ; Fl. Tschuktch. in Engl. Bot. jahrb. XIX. p. 464.

Archangelica Keiskei Miq. Prol. p. 250?

Caule fistuloso erecto multiped. alto glabro, sursum plus minus puberulo, foliis radicalibus.............., mediis et summis biternatisectis, segmentis primariis distincte petiolatis, secundariis sessilibus v. brevi-petiolulatis, segmentis omnibus ovatis v. rhombeo-ovatis basi inæquilateralibus v. confluentibus subæqualiter serratis

ad nervos jugasque foliorum tomentosis ; petiolis basi dilatatis, vaginis superioribus ampliatis aliquando apice auriculatis ; involucro nullo vel 1-phyllo ; umbellis multi (circa 35)-radiatis, radiis inæqualibus ; involucellis polyphyllis linearibus pedicellos subæquantibus subscabris ; umbellulis circa 30-floris, calycis dentibus obsoletis, petalis albis oblongis inflexis ; fructibus oblongis pedicellis æquilongis v. longioribus, jugis primariis æqualibus corticosis, seminibus facie subconvexis nucleatis, vittis minutis ∞, carpophoris bipartitis.

Hab. Japonia boreali : in arenosis littoralibus.

Hokkaidō (Yezo)—Prov. Kitami : in monte Rishiri (5000 pd. 1. Augusto 1899. fl. T. Kawakami) ; Prov. Oshima : Hakodate (Maxim).

Distr. In America boreali, Asia boreali-occidentali, Sachalin, Kamtschatka, Alaska.

Cenolophium Koch.

DC. Prodr. IV. p. 151 ; Endl. Gen. Pl. II. p. 775 ; Benth. et Hook. Gen. Pl. p. 919 (sub Selino) ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 213.

Calycis margo obsoletus, petala obovata emarginata cum lacinula inflexa ; stylopodio brevi conico, stylis reflexis ; fructus oblongus, sectione transversali subteres ; mericarpia 5-juga, jugis æqualibus argutis subalatis ; vittae valleculae 1, commissurae 2. semen semiteres in pericarpio nucleatum—Herba perennis ; folia bi-tripinnatisecta, involucra nulla v. 1-phylla, involucella polyphylla, foliolis linearibus.

Cenolophium Fischeri Koch ? Caule flexuoso glabro sub umbella puberulo ; foliis radicalibus.............. superioribus

tripinnatisectis, segmentis oblongis pinnatifidis lacinulis apice acutis oblongis, petiolis amplis vaginatis oblongis apice plus minus auriculatis ; involucris nullis v. 1-phyllis lineari-setaceis ; umbellis 5—15-radiatis, radiis 2—3 cm. longis intus puberulis, involucellis polyphyllis linearibus setaceis umbellulas fructiferas superantibus ; umbellulis 20—multifloris, pedicellis circiter 1 cm. longis filiformibus, calycis dentibus obsoletis, petalis.............. ; fructibus oblongis 7 mm. longis 4—5 mm. latis cum stylis reflexis, mericarpiis jugis omnibus æqualibus subalatis lateralibus marginantibus fasciculis vascularibus sub margine jugorum sitis, valleculis 1—, commissura 2-vittatis seminibus sectionibus semiteretibus, carpophoro bi-partito.

Cenolophium Fischeri, Koch. Umb. p. 103 ; DC. Prodr. p. 152 ; Ledeb. Fl. Ross. II. p. 282 ?

Hab. Kurile : Shana, ins. Etorofu, (T. Kawakami, Septembri anno 1898. fr !)

Specimen tantum unicum incompletum cum fructibus prostat.

Distr. In Rossia septentrionali, media, australi ; Sibiria Uralensi, Altaica.

Conioselinum Fisch

Hoffm. Umbellif. I. p. 185 ; DC. Prodr. IV. p. 163 ; Endl. Gen, Pl. II. p. 777 ; Benth. et Hook. Gen. Pl. p. 914 (sub Selino); Baill. Hist. d. Pl. VII. p. 210 ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 217.

Calycis margo obsoletus, petala obovata cum lacinula inflexa, stylopodio depresso, fructus oblongus a dorso compressus, mericarpia 5-juga, jugis alatis membranaceis, lateralibus duplo latioribus, valleculae 1-multi-vittatae semen facie planum ; carpophorum bi-partitum

——Herbae perennes, caulis fistulosus, folia bipinnatisecta segmentis pinnatifidis Chaerophylloidea; umbellae terminales multi-radiatae; involucra nulla v. oligophylla, involucelli bracteola lineari-subulata; flores albi.

1. **Conioselinum univittatum** Turcz. Maxim. in Mel. biol. IX. p. 251 (in nota); Rupr. Rev. Umb. Kamtsch. p. 22; Fr. et Sav. Enum. Pl. II. p. 375.

Selinum Benthami S. Wats. "Bibliog. Ind. N. Am. Bot. p. 432."

Herba perennis, caule gracili glabro sursum scaberulo striato supra ramoso striato 30—50 cm. alto. foliis bipinnatisectis. segmentis petiolatis uni-bipinnatifidis, laciniis ultimis oblongis apice mucronatis supra viridibus subtus glaucescentibus; petiolis elongatis basi dilatatis, vaginis superioribus oblongis amplexicaulibus; involucris nullis; umbellis 20—25-radiatis. pedunculis intus scaberulis; involucellis sub-10-phyllis lineari-setaceis scaberulis umbellulis longioribus reflexis persistentibus; umbellulis multifloris. radiolis filiformibus interne puberulis nunc fertilibus nunc sterilibus; calycis dentibus obsoletis, petalis albis obcordatis emarginatis. stylis brevibus erectis demum reflexis; fructibus oblongis, jugis dorsalibus filiformibus v. semialatis, marginalibus alatis. valleculis 1. commissura utrinque 1-vittatis.

Hab. In alpibus Japoniae borealis et mediae. Augusto fl!

Kurile—Makuyomai in Etrofu. (T. Kawakami).

Yezo—Prov. Kitami: in monte Rishiri (T. Kawakami); Prov. Kushiro: in ignivomo Meakan (T. Kawakami).

Honshiu—Prov. Rikuchū: in monte Kurikoma (T. Makino); Prov. Shimotsuke: ad summan montis Shirane in alpibus Nikkō (J. Matsumura); Prov. Kaga: in monte Hakusan.

Distr. Sibiria baikalensi-dahurica.

2. **C. sp.** 1—2 pedali, caule erecto glabro, foliis ternato-

bipinnatisectis, segmentis ovatis v. rhombeo-ovatis apice acutis nec acuminatis, inciso-dentatis, dentibus apiculatis ; petiolis foliorum radicalium elongatis basi dilatatis porphyreo-marginatis amplexicaulibus superioribus saccato-inflatis microphyllis ; involucris 5—6-phyllis lanceolatis albo-membranaceis dorso viridi-lineatis ; umbellis circiter 10-radiatis intus puberulis 2 cm. longis ; involucellis subpentaphyllis, umbellulis brevioribus ; umbellulis 15-floris, calycis dentibus obsoletis, petalis albis oblongis apice acumine inflexis, filamentis petalis vix brevioribus antheris atro-purpureis oblongis, stylis elongatis erectis demum reflexis, fructibus juvenilibus valleculis 1—, commissura 2-vittatis.

Nom. Jap. Senkiu, Kiukiu. 川芎、芎藭

Icon. Jap. Honzōzufu, IX. fol. 4 ; Sōmokuzusetsu, V. fol. 2.

In hortis japonensibus saepe cultum ; fructus mat. nobis ignotus, sed a precedente bene distincta, involucris 5—6-phyllis oblongis, antheris nec atropurpureis, angustioribus. Tota planta odorem aromaticum spirat.

Angelica Hoffm.

Hoffm. Umb. I. p. 158 ; DC. Prodr. IV. p. 167 ; Endl. Gen. Pl. II. p. 778 ; Benth. et Hook. Gen. Pl. I. p. 916 ; Baillon, Hist. d. Pl. VII. p. 207—8 ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 219.

Archangelica Hoffm. Umb. I. p. 16 ; DC. Prodr. IV. p. 169 ; Endl. Gen. Pl. p. 778.

Ostericum Hoffm. Umb. I. p. 164 ; DC. Prodr. IV. p. 167 ; Endl. Gen. Pl. p. 778.

Gomphopetalum Turcz. in Bull. de la soc. Nat. Mosc. 1841. p. 539 ; Endl. Gen. Pl. Suppl. II. p. 69.

Angelophyllum Rupr. Rev. Umb. Kamtsch. p. 8.

Calycis margo obsoletus ; petala oblongo-lanceolata v. ovata acuminata, recta v. inflexa ; fructus a dorso compressus ; mericarpia 5-juga, jugis dorsalibus filiformibus, lateralibus in alas expansis membranaceis ; vittae valleculae solitariae v. 2 ; semen facie planum——Herbae perennes elatae ; folia bipinnatisecta v. ternato-pinnata, vaginis valde ampliatis ; umbellis terminalibus multi-radiatis, involucra involucellaque nulla v. polyphylla ; flores albi.

1. **Angelica anomala** Lallem. " Ind. Sem. Hort. Petr. p. 57 " ; Fr. Schmidt, Fl. Sachal. p. 46 et 137 ; Fr. et Sav. Enum. Pl. Jap. p. 187 ; Fr. Pl. David. p. 141 ; Maxim. Prim. Fl. Amur. p. 127 ; Forbes et Hemsl. Ind. Fl. Sin. p. 333 ; Miyabe, Fl. Kurile. p. 236.

Angelica montana var. angustifolia Ledeb. Fl. Ross II. p. 295.

A. sachalinensis Maxim. Prim. Fl. Amur. p. 127.

Multi-pedalis, caule fistuloso erecto glabro praeter summum in sicco striato supra ramoso ; foliis longe-petiolatis circumscriptione triangularibus ternato-pinnatisectis, segmentis primariis longe petiolatis, secundariis subsessilibus integris v. 3—5-sectis, laciniis rhombeo-oblongis v. lanceolato-oblongis interdum trilobis 10—15 cm. longis 4—6 cm. latis apice acutis argute serratis, supra glabris ad nervos basinque pubescentibus ; petiolis basi dilatatis, vaginis amplisissimis ventricosis, supremis microphyllis, radiis umbellarum purpureis dense pubescentibus ; involucris involucellisque nullis, vel involucellis oligo-phyllis membranaceis, umbellis 40—70-radiatis pedunculis inæqualibus 8—12 cm. longis, umbellulis 50—60-floris, calycis dentibus obsoletis, petalis albis obovatis apice acuminatis valde

inflexis; staminibus petalis vix longioribus, antheris albis, stylis brevibus demum reflexis, pedicellis inæqualibus circa 1—2 cm. longis; fructibus oblongis 8 mm. × 6 mm. basi emarginatis a dorso compressis, jugis tribus dorsalibus nerviformibus, marginalibus alatis; valleculis 1—, commissuris 4-vittatis, carpophoro bipartito.

Nom. Jap. *Yezo-niu.*

Hab. In herbidis per totam Yezo et in montibus altis Honshiu borealis. August fl. et fr.

Kurile—Ins Etorofu: ad Shana et Shibetoro (Sec. K. Miyabe).
Hokkaidō (Yezo)—Prov. Hidaka: Sarubuto (Augusto); Prov. Ishikari: Sorachibuto (K. Miyabe), ad fluvium Toyohira prope urbem Sapporo (J. Matsumura); Prov. Iburi: Oshamanbe (T. Kawakami); Prov. Kushiro: Sempoji (Sec. Miyabe); Prov. Oshima: Hakodate (J. Matsumura).
Honshiu—Prov. Shimotsuke: in monte Nikkō.

Distr. In Sibiria baikalensi, ad Amur inferiorem; China boreali: Mongolia, Chili, Kiangsi; Sachalin.

2. **A ursina** Maxim. in Mel. Biol. IX. p. 652; Fr. et Sav. Enum. Pl. Jap. II. p. 375.

Angelophyllum ursinum Rupr. Rev. Umb. Kamtsch. p. 8; Fr. Schmidt. Fl. Sach. p. 136.

Angelica japonica Gray. (pro parte teste Maxim.) Bot. Jap. p. 390.

Caule glabro fistuloso striato multipedali 4—5 cm. diam. supra ramoso; foliis radicalibus longe-petiolatis ternatis, segmentis late ovatis v. rhombeo-rotundatis 3—5-fidis 20—30 cm. latis, basi cordatis vel rotundatis laciniis rhombeo-ovatis apice acutis rarius obtusis subæqualiter serratis glabris viridulis; petiolis foliorum inferiorum basi dilatatis amplexicaulibus, superioribus vaginis amplisissimis oblongis v. ovatis margine papyraceis microphyllis glabris; involucris nullis aut 1-phyllis foliaceis, umbellis 35—60-radiatis, radiis interne scaberulis 4—12 cm. longis; involucellis 8—10-foliolis lanceolato-linearibus, pedicellis brevioribus; umbellulis 30—40-floris, pedicellis

1—3 cm. longis, calycis dentibus obsoletis, petalis albis oblongo-ellipticis apice acutis involutis, filamentis petalis duplo longioribus, antheris ovato-rotundatis, stylis brevibus stylopodio conico depresso ; fructibus oblongis v. ovalibus 7 mm. longis, commissuris 4 mm. latis basi saepe emarginatis, jugis tribus dorsalibus filiformibus, marginalibus in alas dilatatis, valleculis univittatis superficialibus, commissuris 4-vittatis.

Nom. Jap. Yezoniu, Seiki, Shiukina (Nom. Ainu ex Miyabe et Batchel. Ainu. Econ. Pl. p. 205).

Hab. In pratis humidis per totam Yezo et in sylvaticis alpinis. Honshiu borealis et mediae frequens.

Yezo (Hokkaidō)—Prov. Ishikari: in monte Moiwa prope urbem Sapporo (J. Matsumura); Prov. Iburi: in collibus littoralibus Mororan (J. Matsumura); Prov. Oshima; Hakodate (J. Matsumura).

Honshiu—Prov. Uzen: in monte Hagurosan; Prov. Shimotsuke: in alpibus Nikkō (J. Matsumura, T. Sugiyama) ad declivia Fudōzaka (J. Matsumura); Prov. Shinano: in graminosis sylvaticis montis Wadatōge (ipse) Prov. Kaga: in monte Hakusan: Prov. Shinano: in monte Komagatake et Togakushi.

Distr. Sachalin, Kamtschatka.

3. **A. dahurica** Benth. et Hook. Gen. Pl. I. p. 916 ; Fr. et Sav. Enum. Pl. Jap. 1. p. 187.

Callisace dehurica Fisch. Hoffm. Umb. ed. 2. p. 170 Ledeb. Fl. Ross. II. p. 316.

Hab. Nippon media (sec Fr et Sav.).

Distr. Sibiria.

4. **A. refracta.** Fr. Schmidt. Fl. Sach. p. 138 ; Fr. et Sav. Enum. Pl. Jap. I. p. 187.

A. sylvestris Rupr. (non L!). in Rev. Umb. Kamtsch. p. 10.

Caule erecto inani glabro superne puberulo, foliis inferioribus

longe petiolatis bi-pinnatisectis, petiolis omnibus ad insertionem primarium refractis, inferioribus basi dilatatoattenuatis amplexicaulibus, foliis summis ad vaginas reductis, vaginis oblongis saccato-inflatis ; foliolis omnibus glabris oblongo- lanceolatis apice acuminatis margine argute irregulariterque serratis ad nervos puberulis basi rotundatis inæquilateralibus ; umbellis sericeo-pubescentibus ; involucris nullis ; umbellis 50—60-radiatis, radiis inæqualibus, involucellis oligo phyllis linearibus setaceis pedicellos superantibus ; umbellulis pluri floris, calycis dentibus obsoletis, petalis albis ovatis apice acutis inflexis, filamentis petalis duplo longioribus, fructibus

Caulis $1\frac{1}{2}$—2 m. altus, tenuior quam antecedentibus duobus summo purpureo ; foliola 6—8 cm. longa, $1\frac{1}{2}$—2 cm. lata ; pedunculus 5—7 cm. longus ; involucella 1—$1\frac{1}{2}$ cm. longa.

Nom. Jap. Yezo-Ōbasenkiu ; *Yakara-Kina* (Nom. Ainu sec. Miyabe).

Hab. In humidis sylvaticis, per totam Yezo vulgaris. Prov. Ishikari : in monte ad Jōzankei non procul a Sapporo (J. Matsumura), Ebetsu (H. Yabe) ; Prov. Iburi : in ignivomo Noboribetsu (H. Yabe) ; Prov. Oshima : Hakodate.
Kurile—Naipo in ins. Etorofu (T. Kawakami).
Yedo (sec. Fr. et Sav.) Forsan errata.

Distr. Sachalin.

5. **A. edulis** Miyabe. Caule robusto erecto ramoso sub umbella puberulo ceterum glabro ; foliis ternato-pinnatis, segmentis ambitu deltoideis trilobis basi saepe cordatis, laciniis oblongis v. ovatis apice acutis argute serratis, vaginis summis ampliatis membranaceis reflexis subaphyllis ; foliis omnibus supra viridibus subtus glaucescentibus ad insertionem nervorum tomentulosis; involucro nullo; umbellis multiradiatis, radiis interne puberulis in sicco sulcatis ; involucellis

polyphyllis lanceolatis umbellula brevioribus; umbellulis multifloris inæquipedicellatis, calycis dentibus obsoletis, petalis albis ovato-oblongis antheris albis; stylis brevibus stylopodiis depressis; fructibus oblongis basi emarginatis, jugis tribus dorsalibus nerviformibus, marginalibus alatis, valleculis 1-vittatis commissuris 2-vittatis carpophoro bipartito.

Angelica edulis Miyabe (nomen tantum) in Trans. As. Soc. Jap. p. 205.

Nom. Jap. Ama-niu. Chifue (Nom. Ainu. sec. Miyabe).

Hab. In graminosis Yezo et Honshiu boreali.

Prov. Shiribeshi: Takashima (J. Matsumura); Prov. Hidaka: Shoya (Y. Tokubuchi); Prov. Ishikari: Prope Sapporo (Kawakami).
Honshiu—Prov. Rikuchū: in monte Iwateyama (sec. Miyabe); Prov. Rikuzen: Matsushima; Prov. Uzen (T. Kawakami).

Herba 6—10-pedalis glabra; pedunculus 50—60-radiatus, 5—10 cm. longus; umbellulae 50—60-florae, 8—15 mm. longae; involucella 5 mm. longa; fructus 4 mm. × 6 mm. Ang. ursinae Maxim. maxime affinis, sed fructibus late oblongis nec angustis differt; ab A. anomala Maxim. foliolis latioribus bene separanda!

6. **A. kiusiana** Maxim. in Mel. biol. IX. p. 14; Fr. et Sav. Enum. Pl. Jap. I. p. 187; Forbes et Hemsl. Ind. Fl. Sin. I. p. 334; Palibin, Consp. Fl. Kor. I. p. 98; Bretschneider, Hist. Eur. Bot. Disc. Chin. p. 596; Itō et Matsumura, Tentam. Fl. Lutch. I. p. 531.

A. Sieboldi Miq. Prol. p. 249 (teste Maxim.).

Caule robusto striato ramoso; foliis longe-petiolatis ambitu triangularibus ternato-pinnatis, segmentis subsessilibus vel brevi-petiolatis oblongis 10 cm. longis, 4—5 cm. latis, basi rotundatis subæqualiter serratis; foliolis 3—5-fidis supra nitidulis; petiolis basi dilatato-attenuatis semi-amplexicaulibus, vaginis summis ampliatis

aphyllis ; involucro subpentaphyllo, phyllis anguste triangularibus ; umbellis 30—40-radiatis interne puberulis ; involucelli bracteolis 5—10 lineari-lanceolatis ; umbellulis 30—40-floris ; calycis dentibus parvis, petalis albis ellipticis, filamentis petalis longioribus, stylis brevibus, fructibus oblongis vel ovalibus 1 cm. × 7 mm. latis valde compressis, jugis dorsalibus filiformibus, marginalibus alatis crassis spongiosis, valleculis 1-, commissura 4-vittatis.

Nom. Jap. Oni-udo ; Kujiragusa : Hama-udo.

Icon Jap. Shitsumonhonzō, I. fol. 13 sub. Isoimo?

Hab. In locis apricis maritimis Japoniae australis.

Prov. Sagami : Misaki juxta Yokosuka (medio Julio fr. mat!) ; Prov. Izumi : Tannowa prope oppidum Sakai (S. Matsuda fr!) ; Prov. Kii : Asatani in Niishikagōri (Julio fl!) ; Prov. Nagato : Dannoura (v. v.).
Kiushiu—loco non indicato (Maio fl!) ; Prov. Hizen : in sinum Shimabara prope Nagasaki (sec. Maxim) ; Ins. Tsushima (ipse Augusto fr!).
Bonin (Herb. Makino).
Liukiu (sec. A. Gray).
Formosa : loco non indicato (Uyeno. Maio fl!) et Kelung (T. Makino).

Distr. In archipelago Koreano.

7. **A. utilis** Makino (in sched.). Caule erecto ramoso supra flexuoso sub umbella puberulo cæterum glabro ; foliis radicalibus ternato-pinnatisectis, segmentis rhombeo-ovoideis 2—5-fidis sub duplicato-serratis longe petiolatis, petiolis basi dilatato vaginatis subamplexicaulibus ; foliis superioribus ad vaginas reductis, vaginis ampliatis ovatis albo-membranaceis saccato-cuculatis interdum reflexis ; involucris nullis ; umbellis 12—15-radiatis inæqualibus ; involucelli phyllis 8—10 lanceolato-linearibus acuminatis variabilis aliis brevibus aliis radiolis longioribus ; umbellulis multi-floris, calycis dentibus insignis petalis albis ovatis plus minus inflexoacuminatis, filamentis petalis duplo longioribus antheris albo-flavescentibus, stylis brevibus, stylopodiis depressis margine undulatis, fructibus immaturis oblongis

jugis tribus dorsalibus crassis nerviformibus, marginalibus sub-alatis, valleculis 1 commissuris utrinque bi-vittatis

Archangelica officinalis, A. Gray in List Jap. Pl. p. 312.

Nom. Jap. Ashitaba ; Hachijōsō,

Icon. Jap. Sōmoku-zusetsu, V. fol. 14 ; Kawi, III. fol. 2 ; Honzōzufu, LXX. fol. 16. recto.

Hab. In arenosis littoralibus regionum temperatarum.

Prov. Awa: Hamaogi (T. Makino), Prov. Sagami: Misaki, (T. Tsuchida, et ipse Octobri 20 fl. fr.); Prov. Izu: Shimoda (sec. Gray); Insulis Ōshima et Hachijōshima etc.

Herba perennis, 3—4-pedalis viridis. Omnibus partibus antecedenti magis accedit ; tamen differt foliorum segmentis paulo latioribus minus nitidulis vaginis summis saccato-inflatis albo-membranaceis numerosioribus ; umbellae radiis paucis (12—15), nec pluri-radiatis ut in A. kiusiana. Tota planta succum croceum gummoso-resinosum exsudat! Initio Octobri floret; Novembri fr. mat., sed in A. kiusiana Junio fl. et fine Julii fr!

8. **A. multisecta** Maxim. in Mel. biol. XIII. p. 470.

Radice cylindrico, caule 1—2-pedali glabro erecto fistuloso sub umbella puberulo ; foliis glabris circumscriptione deltoideis 3—5-ternatis, segmentis secundariis distincte petiolulatis, ultimis oblongis, ovatis v. rhombeo-oblongis apice acutis 3—5-fidis margine serrato dentatis serraturis acutis; vaginis summis auriculatis membranaceis reticulatis; involucro nullo; umbellae radiis circa 40 pubescentibus, floribus centralibus fertilibus; involucelli phyllis linearibus vel lanceolato-oblongis umbellulis subæqualibus reflexis; umbellulis 20 vel multifloris, calycis lobis obsoletis, petalis albis oblongis apice acutis inflexis, staminibus petalis longioribus, antheris in sicco atropurpureis,

stylis elongatis reflexis, fructibus ovatis valde compressis velleculis 1—, commissura 2—4-vittatis.

Nom. Jap. Kawazenko.

Icon. Jap. Somokuzusetsu, V. fol. 22.

Hab. In umbrosis alpinis Honsiu mediae.

Prov. Shinano; in monte Ontake (Yatabe; N. Ohno), in monte Komagatake (Augusto fl!) Prov. Kaga; in monte Hakusan.

9. **A. pubescens** Maxim. in Mel. biol. X p. 54.

Caule robusto pubescenti striato supra ramoso; foliis ternato-pinnatisectis, segmentis infimis pinnatifidis, laciniis oblongis v. rhombeo-oblongis apice acutis argute serratis ad nervos pubescentibus, petiolis dense fusco-pubescentibus basi dilatatis supra amplexicaulibus, vaginis superioribus ovatis involucrantibus aphyllis; involucris involucellisque nullis; umbellis 12—15-radiatis, radiis valde inæqualibus 2—9-cm. longis; umbellulis multifloris, calycis lobis obsoletis, petalis albis ellipticis apice acumine involutis, staminibus petalis longioribus, stylis sub anthesin brevissimis demum reflexis; fructibus oblongo-orbiculatis jugis tribus dorsalibus nerviformibus marginalibus alatis, valleculis 2—3-, commissuris 6— vittatis.

Nom. Jap. Takao-Kyōkatsu.

Hab. Prov. Yamashiro; in monte Takao circa Kyōto (T. Makino Octobri fr. mat!)

Tota planta pubescens. Haec species optime cum descriptione Maximowiczeana convenit; tantum differt foliolis oblongis nec ovatis v. ovato-lanceolatis ut cl. Maximowicz descripsit, fructibus 7—8 mm. longis 6½ mm. latis.

var. glabra m. Caule erecto ramoso glabro supra puberulo sulcato; foliis infimis petiolis æquilongis triternatis cæterum bi-triternatis, segmentis primariis petiolatis, foliolis terminalibus trifidis

sectisve basi decurrentibus reliquis ovatis apice acutis basi inæquilateralibus subsessilibus irregulariter serratis, nerviis pilis brevibus pubescentibus; petiolis glabris, infimis basi dilatatis mediis late marginatis tubulosis amplexicaulibus superioribus vaginis cuculatis foliis parvis v. nullis; involucris involucellisque nullis; umbellis 20—40 radiatis, radiis inæqualibus intus scabro-puberulis; umbellulis 20—40-floris, calycis dentibus triangularibus parvis, petalis obovatis apice valde inflexo-acuminatis, staminibus petalis longioribus, antheris albis, stylis brevibus, stylopodio incrassato-depresso, fructibus oblongis utrinque emarginatis, jugis tribus dorsalibus nerviformibus marginalibus alatis valleculis dorsalibus 1—, lateralibus 2 commissuralibus utrinque 3—4-vittatis, carpophoris bipartitis.

Herba perennis 1—2 m. alta; lamina 30—60 cm. longa et lata, foliola 4—5 cm. lata, 10 cm. longa; petiolus 30—50 cm. longus; fructus 8—9 mm. longus, 6 mm. latus.

A. precedenti differt caule glabro nec pubescenti.

Hab. In Tokyo probabiliter spontanea. Fine Septembri fl. Octobri fr. mat!

10. **A. polyclada** Franch. Stirp. nov. v. par. Fl. Jap. in Bull. Soc. Bot. Fr. t. XXXVI. p. 85.

Caule ramoso glabro sulcato vel saepissime pubescenti 1—2 m. alto ad nodam purpureo; foliis inferioribus bi-tripedalis, ternato-bipinnatisectis, segmentis primariis petiolatis, foliolis terminalibus circumscriptione rotundato-ovatis trifidis sectisve basi decurrentibus, lateralibus oblongis vel oblongo-ovatis plerumque inæquilateralibus apice acuminatis v. acutis, foliolis omnibus chartaceis supra viridibus subtus glaucescentibus, æqualiter serratis, sub nerviis pilis brunneis pubescentibus petiolis glabis v. puberulis basi dilatatis, foliolis superioribus subtus pubescentibus duplicato-serratis, vaginis saccato ampliatis, vaginis supremis pubescentibus cuculatis microphyllis

demum reflexis; involucris nullis; umbellis 30—50-radiatis, radiis valde inæquilongis pubescentibus; involucellis nullis; umbellulis circa 60—-floris, calycis dentibus obsoletis, petalis albis oblongis, filamentis petalis duplo triplove longioribus, stylis brevibus divergentibus capitatis demum reflexis, stylopodio crasso conico; valleculis 1—, commissura 2-vittatis.

Cl. Franchet descripsit: "par ses petales sensiblement inegaux, la plante que nous decrivon ici se rapproche des Heracleum," sed in planta nostra petala fere æqualia!

Nom. Jap. Shisi-udo.

Hab. In sylvaticis montanis Japoniae mediae.

Prov. Iwashiro: in monte Iidesan (Yatabe et J. Matsumura, Augusto fl!) in tractu Aizu (sec. Franch, R. Yatabe et J. Matsumura); in monte Adatarōsan (K. Nemoto Augusto fl.); Prov. Shimotsuke: in alpibus Nikkō (Julio fl!); Prov. Shinano: in graminosis ignivomi Asama (Augusto fl! ipse), in monte Wadatoge (fine Julio fl! ipse.); Prov. Musashi: in monte Mitake (ipse, Augusto); Prov. Sagami: circa Yokoska (sec Franch).

11. **A. shikokiana** Makino (in sched.) Caule 2—3 pedali glabro stramineo ramoso; foliis ternato-bipinnatis, segmentis oblongis lanceolatis acuminatis marginibus obsolete-serratis v. integris basi rotundatis, segmentis terminalibus trilobis basi confluentibus glabris subtus glaucescentibus, petiolis ad insertiones foliolorum tomentosis cæterum glabris basi dilatatis amplectentibus; umbellis terminalibus et lateralibus 20—30-radiatis, radiis et caule sub umbella pubescentibus; involucris nullis, involucellis subnullis, umbellulis 20—30-floris, aliis fertilibus aliis sterilibus, calycis dentibus obsoletis petalis albis; fructibus oblongis, jugis dorsalibus 5 quorum 3 mediis nerviformibus, marginalibus subalatis, valleculis 1—, commissura 2—vittatis, carpophoris bipartitis.

Nom. Jap. Inu-tōki (ex Makino).

Hab. Prov. Kii (v. s); Prov. Tosa, ins. Shikoku; Prov. Shimotsuke in montibus Nikko (T. Makino).

Habitus quodamondo Ligustici, sed valleculis uni-vittatis jugis marginalibus alatis differe videtur.

12. **A. nikoensis** m. Caule 2—3 pedali cavo erecto gracile glabro sicco sulcato; foliis infimis triternatisectis, segmentis omnibus petiolulatis, ultimis trilobatis integrisve laciniis oblongis vel rhombeo-oblongis apice acutis basi cuneatis aut inæquilateralibus irregulariter serratis, serraturis acutissimis supra viridibus subtus glaucis, nerviis pubescentibus; petiolis scaberulis basi, dilatatis margine purpureo-membranaceis; superioribus vaginis elongatis involucrantibus cuculatis demum reflexis, foliis parvis v. nullis; involucris nullis vel 1-phyllis; umbellis 11—14-radiatis, radiis et caule superiore pubescentibus, pedunculis inæqualibus $1\frac{1}{2}$—6 cm. longis; involucellis 5—8-phyllis linearilanceolatis uninerviis umbellam æquantibus; umbellulis circa 12—20-floris, calycis dentibus triangularibus minutis, petalis albis ad margines purpurascentibus oblongis apice acutis, staminibus petalis longioribus, stylis brevissimis; fructibus oblongis jugis tribus dorsalibus æqualibus crassis, marginalibus alatis, vittis valleculis 1—, lateralibus rarius 2, commissuris utrinque 1. carpophoris bipartitis.

Caulis 2—3 pedalis; foliola 10 cm. longa, 4—5 cm. lata; pedicellus 3—5 mm; fructus 7 mm. longus, 4 mm. latus.

Folia iis Peucedani decursivi Max. similia, sed serraturis argutioribus, foliolis omnibus petiolulatis.

Hab. Prov. Shimotsuke: in monte Nikkō (J. Matsumura Octobri fr!).

13. **A. saxicola** Makino. (in Sched.). Herba perennis tenera humile, caule sulcato subramoso tomentoso; foliis plerumque radicalibus longe petiolatis ternatis, segmentis primariis distincte petiolulatis ternatifidis vel partitis; partionibus rhombeis v. oblongis

pinnatifidis, lacinulis oblongo-lanceolatis 3—5-serratis, serraturis apice acutis; foliolis omnibus supra viridibus nitidulis ad venas puberulis subtus glaucescentibus; petiolis inferioribus dilatatis, superioribus sessilibus; vaginis oblongo-membranaceis reticulatis, foliis minimis vel nullis; involucris 1-phyllis lanceolatis; umbellis terminalibus fertilibus lateralibus sterilibus multi-radiatis, radiis intus scabro-puberulis; involucellis sub-10-phyllis lineari-lanceolatis ad basin angustis 1-nerviis umbellulis æqualibus vel etiam longioribus; umbellulis multifloris, pedicellis inæquilongis, calycis lobis parvis, petalis albis oblongis apice acutis involutis, staminibus petalis duplo longioribus; stylis brevibus demum elongatis reflexis, stylopodio conico; fructibus (immaturis) oblongis................

Sesquipedalis, petiolis 10—12 cm. longis; foliolis 3 cm. longis $1\frac{1}{2}$ cm. latis; pedunculus 5—3 cm. longus; involucella c. $1\frac{1}{2}$ cm. Precedenti valde affinis, differt foliolis nitidulis nec ovatis, nec tenŭis, involucellis brevioribus.

Nom. Jap. Iwa-zeri (Makino).

Hab. Shikoku—in monte Ishizuchi.

14. A. **Matsumurae** m. Caule erecto glabro sub umbella puberulo ramoso; foliis biternatisectis, segmentis tri-quinque pinnatipartitis, laciniis lanceolato-oblongis basi decurrentibus margine argute dense serratis; foliis supra ad nervos pubescentibus; radiis umbellarum circa 40 valde inæquilongis puberulis; involucris involucellisque nullis; umbellulis multifloris pedicellis filiformibus pubescentibus, calycis lobis obsoletis petalis albis ovato-oblongis apice inflexis, staminibus petalis duplo triplove longioribus, antheris atropurpureis, stylis brevissimis purpureis stylopodio incrassato; fructibus oblongis valleculis dorsalibus 1—, lateralibus 2—3, commissuralibus utrinque vulgo trivittatis.

A. anomalae Lall. affinis, differt foliis supra ad nervos pubescentibus, marginalibus argute serratis serraturis numerosioribus, radiis umbellarum circa 40, fructibus jugis marginalibus densioribus.

Hab. Prov. Shimotsuke; Yumoto in monte Nikkō (J. Matsumura) Octobri fr!

15. **A. sp.** Caule robusto sub umbella scabro-puberulo; foliis longe petiolatis ternato—bipinnatis, segmentis lanceolato-ovatis acuminatis margine irregulariter serratis, serraturis acutis supra viridibus subtus glaucis sessilibus basi rotundatis v. cuneatis; petiolis amplexcaulibus summis involucrantibus microphyllis, involucris nullis, umbellis pluriradiatis (60), radiis scaberulis involucellis subnullis; umbellulis multifloris; calycis dentibus obsoletis, petalis albis ovatis acuminatis involutis staminibus petalis vix longioribus, stylis brevibus, fructibus...............

Ab A. anomala Lall. differt caule striato foliis augustioribus serraturis densioribus. Cum Angelica Razuli Gouan. comparanda?

Hab. Hokkaidō—Prov. Kitami: in ins. Rishiri (T. Kawakami, Julio anno 1899.).

16. **A. Florenti** Fr. et Sav. in Maxim. Mel. biol. IX. p. 251; Fr. et Sav. Enum. Pl. Jap. I. p. 188.

Caule tereti humile erecto glabro sulcato subramoso; foliis longe petiolatis circumscriptione triangularibus bi-pinnatisectis, segmentis pinnatifidis petiolulatis laciniis lanceolato-linearibus integris v. serratis; petiolis laminis duplo longioribus basi dilatatis amplexicaulibus, summis nullis, vaginis foliorum superiorum ovatis margine membranaceis; involucris 1—4-phyllis ovatis acutis subulatis radiis brevioribus; umbellae radiis 5—8 subaequalibus in sicco angulatis; involucellis pleiophyllis linearibus ovatisve 1-nerviis pedicellos sub-

æquantibus; umbellulis circa 20-floris aliis fertilibus aliis sterilibus, calycis dentibus distinctis ovatis acutis, petalis albis ovatis apice acuminato-inflexis ob costam leviter constrictis, stylis brevissimis nec reflexis fructibus ovato-orbiculatis, jugis tribus dorsalibus angustis marginalibus late alatis, valleculis 1-, commissura 2-vittatis.

Nom. Jap. Shirane-ninjin.

Icon. Jap. Sōmoku-zusetsu, V. fol. 18.

Hab. Prov. Sagami: in montibus Hakone (S. Okubo Octobri fr. mat!); Prov. Shimotsuke: in summis montis Shirane (J. Matsumura); Prov. Shinano: in monte Ontake (Julio 1880); Prov. Kaga: in alpibus Hakusan; in montibus altis Japoniae boreali frequens!

Peremis, 1—2-pedalis; petiolus inferior 15 cm. longus; lamina 7 cm. longa, 6 cm. lata, segmentum ultimum 7 × 2 mm; pedunculus $1\frac{1}{2}$—2 cm. longus; fructus 4 mm. × 5 mm.

Specimina prostant in montibus Prov. Shinanoe lecta caulibus gracilibus, foliis pinnato-decompositis, segmentis ultimis anguste-linearibus, involucellis lanceolato-ovatis apice acuminatis margine albo-membranaceis umbellulam æquantibus vel vix superantibus, stylis elongatis reflexis. An species forsan distincta?

17. **A. Miqueliana** Maxim. in Mel. biol. IX. p. 255; Fr. et Sav. Enum. Pl. Jap. II. p. 375; Franch. Pl. David. I. p. 142; Hemsl. et Forbes, Ind. Fl. Sin. I. p. 334.

Caule sulcato-ramoso glabro; foliis ternato-bipinnatisectis, segmentis rhombeo-ovatis apice acutis basi emarginatis v. rotundatis, terminalibus præsertim cuneatis decurrentibus v. subsessilibus 4—8 cm. longis, 3—6 cm. latis grosse dentatis, dentibus apice mucronulatis, petiolis basi vaginatis; foliolis superioribus oblongo-lanceolatis vaginis ampliatis; involucris nullis vel 1—2-phyllis lanceolatis foliaceis 1—$3\frac{1}{2}$ cm. longis; umbellis 5—8-radiatis intus scabro-puberulis

inæqualibus ; involucellis 5—6-phyllis lanceolatis pedicellis brevioribus ; umbellulis 15—20-floris, pedicellis 2—7 mm. longis, floribus masculis brevibus, calycis dentibus parvis v. acutis prominulis 1-nervis, petalis albis subinæqualibus obcordatis apice emarginatis cum lacinula inflexis filamentis petalis æquilongis, antheris albis, stylis sub anthesin erectis dein reflexis; stylopodio conico-depresso; fructibus oblongis obovatisve valleculis 1—3-, commissura 6—8-vittatis.

Nom. Jap. Yama-zeri.

Icon. Jap. Sōmokuzusetsu, V. fol. 23.

Hab. Japonia media : in umbrosis sylvaticis et valleculis humidis. Octobri fl.

Prov. Rikuchū : in tractu Nambu (sec. Maxim.) ; Prov. Shimotsuke : in alpibus Nikkō (J. Matsumura Octobri fl.) ; Prov. Shinano : loco non indicato (D. Takashima no. 8.) ad. pedem montis Shirouma (ipse Augusto fl !) ; Prov. Musashi : circa urbem Tokyo (Octobri fl.), in montibus Chichibu (ipse !) ; Prov. Sagami : in montibus Hakone (sec. Maxim ! T. Makino, S. Okubo !) ; Prov. Omi : in monte Ibukiyama (ipse, septembri fl !) ; Prov. Tosa : Tachikawa (Herb. T. Makino) ; Kiushiu : in monte Kundshosan (sec. Maxim.).

Distr. China boreali : Chili, Mongolia.

18. **A. polymorpha** Maxim. in Mel. biol. IX p. 187 et 257 ; Fr. et Sav. Enum. pl. Jap. II. p. 375 ; Bretschn. Hist. Eur. Bot. Disc. p. 596.

Caule cavo erecto glabro sub umbella puberulo ad nodos purpurascenti cæterum viridi ; foliis radicalibus deltoideis ternatotripinnatis membranaceis, segmentis primariis secundariisque longe petiolulatis ultimis brevi petiolulatis v. subsessilibus ovatis v. rhombeo-oblongis 3-lobis v. integris profunde inciso-serratis, serraturis mucronulatis ; petiolulis interdum reflexis summis ad vaginas elongatolanceolatis cuculatis microphyllis ; involucro nullo ; umbellis terminalibus et lateralibus sub 20-radiatis, radiis interne puberulis ; involucellis sub 5-phyllis linearibus puberulis umbellulas æquantibus ;

umbellulis multifloris pedicellis 1—1½ cm. longis, calycis dentibus saepissime obsoletis vel brevibus, petalis albis obovatis apice acuminatis inflexis, staminibus longioribus, antheris albis, stigmatibus capitatis stylis brevibus demum valde elongatis reflexis; fructibus quadratis basi cordatis, jugis dorsalibus subæqualibus marginalibus alatis nec papilaceis, valleculis 1-, commissura 2-vittatis, minutis.

Nom. Jap. *Suzuka-zeri*; *Shirane-senkiu*; *Yamasenkiu*.

Icon. Jap. Honzo-zufu, IX. fol. 7 sub Suzukazeri.

Hab. Per totam Japoniam in sylvis umbrosis subalpinis Septembri—Octobri fl! Prov. Rikuzen: circa urben Sendai (Herb. Yasuda Octobri fl!); Prov. Iwashiro: Tsuchinoyu, in tractu Aizu (K. Nemoto); Prov. Shimotsuke: in alpibus Nikkō, ad Chūzenji (J. Matsumura Octobri fr. mat!), ad montem Shirane (fine Septembri fl!); Prov. Musashi: in declivitate sylvatica Kobotoke (ipse); Prov. Sagami: in montibus Hakone (Tschonoske sec. Maxim. ipse Octobri fl!); Prov. Suruga: in vulcano Fuji (Herb. Makino); Prov. Shinano: in monte Togakushi; Prov. Kaga: ad pedem montis Hakusan (R. Yatabe); Prov. Kawachi: in monte Kōngōsan (K. Nagano; T. Tada.); Prov. Ise: in monte Suzuka (ex K. Tani), in montis Komono (K. Tani); in monte Kyōgamine (K. Tani).

Shikoku—Prov. Awa: in pago Shinryo (N. Oyatsu no. 91); Prov. Tosa: in monte Kurotaki (T. Makino); Prov. Iyo: Naose (T. Makino).

Kiushiu—Prov. Bungo: prope Ōita (A. Ideta); in jugo Kundshosan (sec. Maxim).

19. **A. hakonensis** Max. in Mel. biol. IX p. 257; Fr. et Sav. Enum. Pl. Jap. II. p. 375; Bretchneider, Hist. Eur. Bot. Disc. Chin. p. 896.

Perennis 2—6-pedalis, caule erecto ramoso viridi vel purpurascenti ramis innovantibus pubescentibus; foliis inferioribus longe petiolatis bipinnatisectis, segmentis petiolulatis trifidis, foliis superioribus 2-vel 3-ternatis glabris, lacinulis omnibus foliorum supra viridibus ad nervos purpureis rhombeo-lanceolatis v. oblongis 1—4 cm. latis, 4—10 cm. longis acuminatis basi cuneatis v. truncatis irregulariter serratis v. duplicato-serratis, serraturis apice acutis; petiolis inferioribus basi dilatatis amplexicaulibus, vaginis caulinis

oblongis, summis rotundatis saccato-inflatis viridibus plus minus purpureis; involucro nullo vel 1-phyllo foliaceis; umbellis 10—15-radiatis, radiis elongatis 3—5 cm. longis angulatis intus puberulis purpureis, involucelli foliolis 5—10, lanceolatis vel setaceis umbellulam superantibus 15 mm. longis 1-nerviis reflexis puberulis; umbellulis 15—25-floris, pedicellis 2—7 mm. longis, calycis dentibus obsoletis vel setulosis, petalis obovatis acutis inflexis margine et in medio atropurpureis; filamentis petalis duplo longioribus purpureis, antheris albis, stylis brevibus, stylopodio depresso margine undulato; fructibus ovalibus jugis dorsalibus carinatis conspicuis lateralibus in alas dilatatis, valleculis 1-, commissura 4-vittatis, seminibus facie convexis.

Planta succum croceum gummosum exsudat. Interdum occurant specimina petalis 6, staminibus 6, mericarpiis 3.

Nom. Jap. Iwa-ninjin.

Hab. In sylvaticis humidis Hakone (Tschonoske, sec. Maxim! S. Okubo, 9. Octobri 1890; ipse, 18 Octobri 1899. fl. fr. nondum mat.).

20. **A inæqualis** Maxim. Mel. biol IX. p. 186 et p. 258.

Archangelica inæqualis Maxim. in Fr. et Sav. Enum. Pl. Jap. I. p. 188.

Caule gracili glabro fistuloso erecto, foliis glabris tenuibus ternato-pinnatisectis, segmentis pinnatilobis irregulariter inciso-crenatis membranaceis laciniis oblongis vel ovato-lanceolatis acuminatis basi cuneatis, petiolis basi dilatatis elongatis margine membranaceis purpurascentibus; foliis summis minutis vaginis oblongis, involucro 1-phyllo aut nullo; umbellis 5—10-radiatis valde inæquilongis aliis 7 cm. attingentibus, aliis $1\frac{1}{2}$ cm. longis glabris; involucelli foliolis 6—8 linearibus pedicellis æquilongis v. brevioribus; umbellulis 6—20-floris; fructibus oblongis jugis dorsalibus tribus filiformibus

marginalibus alatis basi emarginatis valleculis 3—4-, commissura 6-vittatis, carpophoris bi-partitis.

Nom. Jap. Hanabi-zeri.

Hab. Japonia media—Prov. Mikawa: in monte Hongūsan (Nagura in herb. Makino); Prov. Tosa in ins. Shikoku: in monte Kurotaki (T. Makino octobri fr!), in monte Yokogura (T. Makino).

CONSPECTUS SPECIERUM ANGELICARUM.

I. Herbae humiles (1—2 pedales).

1. Foliorum laciniae lineares integrae .... Florenti.
   ,, ,, ovatae v. oblongae 2
2. Foliola oblonga v. ovata, antherae atro-purpurae...... multisecta.
   ,, oblonga v. rhombeo-oblonga antherae albae...... saxicola.

II. Herbae elatae (3-multipedales).

1. Valleculae 1-vittatae 2
   Valleculae 2—3-vittatae 9
2. Foliola ad jugam refracta, oblonga dense serrata......... refracta
   Commissurae 2-vittatae 3
   Commissurae 4-vittatae 6
3. Pericarpia spongiosa .... dahurica.
   Antherae et petalae ad margines purpurae .... hakonensis.
   Antherae albae.. 4
4. Inovolucra et involucella nulla 5
   Involucrum nullum, involucella polyphylla, fructus oblongus, planta multi-pedalis .... edulis.
   Involucrum nullum, involucella sub 5-phylla, fructus quadrato-oblongus, c. 3-pedalis.. polymorpha.
5. Foliorum laciniae oblongo-ovatae dense serratae ...... polyclada.

Foliorum laciniae oblongo-laceolatae laxe serrulatae iis Ligustici acutilobi similes .... shikokiana.

6. Planta littorales meridionales.. 7

Planta septentrionales 8

7. Involucra 5-phylla. umbella 30—40-radiata. fructus ellipticus late alatus .... kiusiana

Involucra nulla. umbella 12—15-radiata. fructus oblongus anguste alatus .... utilis.

8. Foliorum segmentae oblongae, involucella nulla......... anomala.

Foliorum segmentae late ovatae v. rhombeo-rotundatae, basi saepe cordatae, involucella oligophylla .... ursina.

9. Involucella nulla 10

Involucella oligophylla 11

10. Antherae albae .... pubescens.

Antherae atropurpurae .... Matsumurae.

11. Foliorum segmentae pinnatilobatae, lobis inciso-serratis......... .... inæqualis.

Foliorum segmentae serratae .... Miqueliana.

Phellopterus Benth.

Benth. et Hook. Gen. Pl. I. p. 905 ; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 221.

Glehnia Fr. Schmidt. in Miq. Pl. Lug. Bat. III. p. 61 ; Baillon Hist. d. Pl. VII. p. 215.

Calycis lobi parvi membranacei ; petala ovato-lanceolata v. angusta, acumine longe inflexa, ob costam superne impressam emarginata ; stylopodia depresso-conica subintegra ; fructus subpyriformis, transverse subteres, commissura lata ; carpella subteretia ;

juga primaria omnia æqualia in alas crassas suberosas dilatata ; vittae ∝, cum endocarpio tenui ab exocarpio solutae et summi arcte adhærentes ; carpophorum bi-partitum ; semen facie late excavatum——Herba diffusa villosa; folia 2—3-ternatim v. sub-pinnatim dissecta, segmentis obovatis denticulatis subincisisve, crassiusculis villosis v. demum glabratis. Umbellae (folia saep vix superantes) compositae, ∝-radiatae, umbellulae compactae villosae ; involucri folia 1—2 v. 0, involucelli ∝ ; flores parvi polygami ; fructus majusculi villosi maturitate vix glabrascentes.

Phellopterus littoralis Benth. in Benth. et Hook. Gen. Pl. I. p. 905 ; Fr. Schmidt, Fl. Sach. p. 138 ; Franch. et Sav. Enum. Pl. Jap. I. p. 185 ; Hance in Journ. Bot. (1878) p. 11 ; Coult. et Rose, Rev. N. Am. Umb. p. 81 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 331 ; Palibin, Consp. Fl. Kor. I. p. 97 ; (1898) ; Itō et Matsumura, Tentam. Fl. Lutch. I. p. 262.

Glehnia littoralis Fr. Schmidt, ex Miq. Prol. Fl. Jap. P. 249.

Cymopterus littoralis A. Gray, Bot. Jap. in Mem. Am. Acad. VI. p. 391.

Herba perennis humilis villosa, foliis biternatisectis, segmentis integris vel trilobis orbiculatis rhombeo-ellipticis v. elongatis basi cuneatis v. rotundatis attenuatis margine cartilagineis æqualiter serratis, superne nitidulis viridibus rigidulis subtus puberulis ; petiolis villosis basi dilatato-attenuatis vaginis margine membranaceis ; umbellis compositis terminalibus axillaribusque 12-radiatis ; involucris nullis ; pedunculis villosis inæqualibus ; involucellis nullis, pedicellis brevibus inæqualibus valde villosis, calycis dentibus prominulis acutis triangularibus uninerviis, petalis albis obovatis cum lacinula inflexis ; fructibus ovatis 5-jugis, jugis prominulis crasso-alatis

marginalibus latioribus, pericarpiis corticosis, seminibus facie convexis semi-lunaribus, vittae ∞, pericarpio adhærentibus.

Nom. Jap. *Hama-bōfū*, *Yaoya-bōfū*, *Ise-bōfū*.

Hab. In arenosis littoralibus per totam Japoniam.

Ins. Kurile: in Sikotan (Herb. Kawakami).
Hokkaidō (Yezo)—Prov. Iburi: Usu (T. Kawakami); Prov. Hidaka: Horomanbetsu (G. Tokubuchi), Iwanai; Prov. Kitami: ins. Rishiri (S. Hori): Prov. Oshima: Hakodate (R. Yatabe), Mori (T. Kawakami).
Honshiu—Prov. Kazusa: Ichinomiya; Prov. Sagami: Misaki (ipse! Julio fl. fr!), Kamakura (K. Tsuji); Prov. Izu: ins. Miyakejima; Prov. Ise: Akogiura circa oppidulum Tsu (K. Tani); Prov. Izumi: Sakai (S. Matsuda Julio fr! K. Nagano Junio fl!): Prov. Settsu: Ichinotani (Majo. fl).
Kiushiu—Prov. Chikuzen: in promontorium Najima (K. Nagano); Prov. Hizen: Karatsu (Kusaba in herb. Kawakami); Prov. Bungo: Oita (A. Ideta); Ins. Tsushima: Kuroshima (ipse Auguto fl. fr.).
Liukiu—loco non indicato (H. Nakagawa, Wright); ins. Kumeshima (H. Kuroiwa); ins Amami-Oshima (ex Tashiro); ins. Okinawa (ex Tashiro); ins. Kurushima (A. Tashiro sec. Ito); ins Okinawa: in tractu Kundjan ad Nagomakiri (S. Tanaka, no. 82.).

Distr. Korea, China, Manchuria australi, Sachalin, America australi.

Ferula L.

Ferula communis L. Sp. 355. rarissime culta.

Peucedanum L.

Linn. Gen. n. 339; Koch, Umb. 92; DC. Prodr. IV. p. 176; Endl. Gen. Pl. p. 779; Benth. et Hook. Gen. Pl. I. p. 918; Baillon, Hist. d. Pl. VII. p. 204; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 234.

Calycis dentes obsoleti v. parvi; petala late ovata acuminata cum lacinula inflexa, stylopodia crassa conica margine undulata; fructus a

dorso plano compressus ellipticus v. ovatus vel basi emarginatus, ugis primariis dorsalibus subæqualibus, lateralibus in alas dilatatis arcte contiguis, valleculae 1-vittatae, laterales subinde 2—3-vittatae, commissura saepe 2-, rarius 6-vittata ; carpophorum bipartitum ; semen complanatum, facie planum—Herbae perennes glabrae, folia pinnata v. ternato-pinnatisecta, umbellae compositae terminales, involucri foliola ∞ v. 0 ; flores albi vel purpurei.

1. **Peucedanum japonicum** Thunb. Fl. Jap. p. 117 ; Spreng. Syst. Veg. 1. p. 911 ; DC. Prodr. IV. p. 182 ; Fr. et Sav. Enum. Pl. Jap. I. p. 189 ; Itō et. Matsumura, Tent. Fl. Lutch p. 264.

Ligusticum acutilobum Miq. Prol. p. 248 (non S. et Z.).

Caule erecto vel subflexuoso glabro v. puberulo ramoso, foliis inferioribus longe petiolatis basi dilatatis, superioribus sessilibus vaginis latis auriculatis margine membranaceis, foliis ternatisectis segmentis petiolatis basi cordatis vel attenuatis trifidis, laciniis rhombeo-obovatis duplicato-crenulatis glabris glaucis ; involucris 4—5-foliolis setaceis pubescentibus ; umbellis sub 20-radiatis, radiis inæqualibus pubescentibus ; involucelli bracteolis 5—8-phyllis triangularibus lanceolatisve acutis umbellulas æquantibus pubescentibus ; umbellulis 25-floris, calycis dentibus obsoletis puberulis, petalis albis ovatis acutis involutis dorso dense pubescentibus, fructibus oblongis, jugis subæqualibus, valleculis 3—4-,commissuris 8-vittatis.

Nom. Jap. Botan-ninjin, Botan-bōfū, Kezuri-bōfū.

Icon. Jap. Sōmoku-zusetsu, V. fol. 13.

Hab. In arenosis littoralibus Japoniae australis et mediae. Julio fl. Prov. Awa: Hamaogi (T. Makino) ; Prov. Musashi : Hommoku non procul a Yokohama (Herb. Makino) ; Prov. Sagami : Misaki et circa Yokoska (ipse Julio fl ! Septembri fr.) ; Prov. Owari : loco non commemorato ; Prov. Kaga : juxta Kanazawa (T. Ichimura).

Shikoku—Prov. Iyo: Takahama (T. Makino).

Kiushiu—Prov. Hizen: Karatsu sinus Simabarae (Herb. Kawakami), Nagasaki: Prov. Hiuga: Tsuno (Herb. Mus. Imp.)

Liukiu—Ins. Amami-Oshima, inter Nishinakama et Naze (sec. Ito); Ins. Okinawa (Tashiro); Ins. Kumeshima (Kuroiwa); ins Kurushima (A. Tashiro).

Formosa septentrionali: juxta Tamsui (B. Hayata).

2. **P. decursivum** Maxim. in Mel. biol. XII. p. 472; Hemsl. et Forbes, Ind. Fl. Sin. I. p. 335; Henry List Pl. Form. p. 47; Palibin, Consp. Fl. Korea. I. p. 98.

Angelica decursiva Fr. et Sav. Enum. Pl. Jap. I. p. 187; Franch. Pl. David. I. p. 142; Hance in Journ. Bot. (1883) p. 321; Diel. Fl. Centr. China p. 500.

Porphyroscias decursiva Miq. in Prol. Fl. Jap. p. 250; A. Kanitz, Anthoph. Jap. leg. p. 28.

Herba perennis, caule erecto 3—6-pedali glabro striato sub umbella puberulo, ad nodas purpureo; foliis radicalibus caulinisque ternatisectis, segmentis trifidis v. quinque-pinnatifidis glabris laciniis oblongis crenatis v. serratis basi decurrentibus, petiolis basi dilatatis vaginis purpureis, foliis superioribus in vaginas reductis saccato-inflatis demum reflexis; involucris 1—2-phyllis ampliatis membranaceis persistentibus umbellis 20-radiatis 1—1½ pollicaribus; involucellis 5—7-phyllis lineari-lanceolatis v. lanceolatis, umbellulis fructiferis vix longioribus; umbellulis sub 20-floris, calycis dentibus obsoletis petalis teneris violascenti-purpureis oblongis apice acutis, antheris purpureis filamentis atro-purpureis v. albis petalis longioribus patentibus; fructibus a dorso compressis, jugis dorsalibus minus prominentibus, marginalibus expansis alatis valleculis 1—3-vittatis, commissura 4—6-vittata; seminibus facie sub-planis.

Nom. Jap. Nodake, Udana, Nozeri, Komazeri, Zenko.

Icon. Jap. Honzōzufu, VII. fol. 12. sub Zenko, Udana; Honzō-

kōmokukeimōzufu, IX. fol. 10 sub Komazeri ; Sōmoku-zusetsu, V. fol. 33. sub Nodake.

Hab. In collibus apricis et in fruticetis ad oras sylvarum Japoniae mediae etiam inFormosa frequens. Prov. Hitachi: Yūki; Prov. Shinano: loco non indicato (D. Takashima ! no. 9.); Prov. Shimōsa : Shimoshizu (T. Makino); Prov. Sagami: circa Yokoska (octobri fl.); Prov. Musashi : circa Tokyō (fine Septembri fl. Novembri fr. mat !); Prov. Mikawa : Fukamizo (Kirito); Prov. Ōmi : in monte Ibuki (K. Tsuji); Prov. Kaga : in monte Hakusan; Prov. Izumi: Ushitaki (S. Matsuda); Prov. Harima: Kashimamura (U. Ōgami); Prov. Yamato: loco non indicato (Herb. Mus. Imp). Shikoku—Prov. Iyo : in monte Ishizuchi (R. Yatabe).
Kiushiu—Prov. Bungo : Ōita (A. Ideta); Prov. Chikuzen : in Kasuyagōri (K. Nagano no. 136); Prov. Higo: in vulcano Aso (ipse Augusto fl,); Ins. Tsushima : Izuhara (ipse Angusto fl.).
Formosa—Tamsui (Oldham sec. Hemsl. T. Makino).

Distrib. Korea, China australi: Hanchow (Ch. Owatari, Julio fl.)

forma albiflorum (Maxim). Mel biol. XII. p. 472, floribus albis.

Nom. Jap. Shirobana-nodake

Icon. Jap. Honzōzufu, VII. fol. 12.

Hab. Prov. Musashi : circa Tokyo (octobri fl,); Prov. Echigo : Nagaoka (S. Ideta) Prov. Higo in ins Kiushiu : in vulcano Aso (ipse.).

3. P. terebintaceum Fisch. ex Turcz. Cat. Baikal. no. 539 ; Lebeb. Fl. Ross. II. p. 314 ; Maxim. Prim. Fl. Amur. p. 128 ; Franch. Pl. David. p. 143 ; Forbes et Hemsl. Ind. Fl. Sin. I. p. 335 ; Palibin, Consp. Fl. Korea I. p. 98 ; Diels, Fl. Centr. China p. 502.

Selinum terbinthaceum Fisch. in Spr. Syst. Veg. I. p. 909.

Herba perennis, caule erecto glabro sulcato ramoso sursum scaberulo ; foliis circumscriptione ovatis, inferioribus longe petiolatis ternato-bipinnatis, segmentis primariis petiolulatis ovatis vel oblongis basi decurrentibus, tertiariis oblongis pinnatifidis ; foliis superioribus trisectis bipinnatifidisque ; laciniis ultimis omnium foliorum oblongo-

lanceolatis apice mucronatis ; petiolis foliorum inferiorum vaginato-attenuatis marginibus membranaceis, vaginis superioribus apice auriculatis margine in sicco rubelulo-purpureis ; involucris polyphyllis, phyllis linearibus deciduis ; umbellis 18—24-vulgo 20-radiatis 1—3 cm. longis inæquipedunculatis intus scaberulis ; involucellis 6—8 v. multi-phyllis lanceolato-linearibus umbellulam æquantibus v. superantibus ; umbellulis multifloris, calycis dentibus triangularibus, petalis lato-ovatis acuminatis inflexissimis rubellis, antheris albis, stylopodio conico margine integro, fructibus orbiculato-oblongis, valleculis 1-, commissura 2-vittatis.

Caulis 60 cm. altus viridis ; folia radicalia petiolis inclusis 25 cm. longa, umbellae 18—24 radiatae, radiis inæqualibus 1—3 cm. plerumque 2 cm. longis.

Hab. Hokkaidō (Yezo)—Prov. Hidaka : Horomanbetsu (Y. Tokubuchi ! Augusto fl.) ; Prov. Ishikari—ad rivulum Toyohira prope Sapporo (J. Matsumura ! initio Augusti 1899 fl. T. Kawakami ; A. Ideta).

Distr. Korea ; China boreali, Mandschuria et Dahuria.

4. P. multi-vittatum Maxim. in Mel. biol. XII. p. 47 ; Bretschneid. Hist Eur. Bot. Disc. Chin. p. 597.

Herba perennis 1-pedalis, caule erecto fistuloso glabro sub umbella pubescenti oligophyllo ; foliis radicalibus et inferioribus bi-ternatis, segmentis primariis petiolatis, secundariis sessilibus v. petolulatis late ovatis v. oblongo-ovatis acutis nunc obtusis bi-trilobis inciso-serratis, segmentis secundariis ovatis profunde tri-lobis, lobis anguste oblongis inciso-dentatis ; caulinis superioribus trisectis ovatis inciso-serratis ; petiolis foliorum inferiorum elongatis vaginis ampliatis oblongis auriculatis membranaceis, superioribus rotundatis, ad insertionem petiolulorum pubescentibus ; involucris nullis ; umbellulis 7—10-radiatis, radiis c. 2 cm. longis intus pubescentibus ; involucellis

oligophyllis, phyllis lanceolatis acuminatis inæqualibus ; umbellulis 8—12 floris, calycis lobis oblongis acuminatis, petalis late ovatis apice unguiculatis involutis, staminibus petalis subæqualibus stylis brevibus patulis ; fructibus ellipticis alatis jugis dorsalibus nerviformibus, vittis tenuissimis passim ramosis numerosis, carpophoro bipartito.

Nom. Jap. Hakusan-bōfu, Hirohaninjin.

Hab. Prov. Uzen, in Japonia boreali: in summitatis montis Gassan (Julio fl.) Prov. Shinano: in monte Asama (Herb. Mus. Imp), in monte Komagatake (Augusto fl.), in monte Shiroumayama (ipse! Augusto fr.); Prov. Etchū: in monte Tateyama (Julio fl.); Prov. Kaga: in altissimis montis Hakusan (Augusto fl. R. Yatabe).

5. **P. deltoideum** Makino (in Sched.). Radice cyrindrico, caule glabro ramoso sub umbella scaberulo; foliis glabris subtus glaucescentibus ternatim-bipinnatis, segmentis ultimis oblongis v. rhombeo-oblongis pinnatim v. bipinnatim dentatis serratis, petiolis inferioribus basi dilatato-vaginantibus, superioribus cum vaginis latioribus margine membranaceis amplectentibus ; involucris nullis v. oligo-phyllis linearibus ; umbellis 10—15-radiatis interne scaberulis ; involucellis 6—8-phyllis linearibus pedicellis brevioribus inæqualibus demum reflexis ; umbellulis multifloris, calycis dentibus triangularibus parvis, petalis albis late cordatis cum lacinula inflexa, filamentis petalis subæquantibus, stylis elongatis, stylopodio conico, fructibus orbiculato-ellipticis, jugis dorsalibus et lateralibus leviter prominulis, marginalibus alatis, valleculis univittatis; seminibus facie sub-planis, vittis superficialibus.

Caulis 1—2 pedalis purpurascens ; folia rigidula absque petiolo 15 cm. v. multicm. longa ; umbellae 7—10-radiatae 1½—2 cm. longae ; involucella pedicello breviora ; petala alba.

Modo crescendi P. terebinthacei Fisch. affinis, sed altior ; differt

imprimis foliis rigidulis, involucellis brevioribus, umbellis paucis, involucris nullis v. oligo-phyllis, petalis albis nec rubellulis, floribus masculis intermixtis. An P. Sieboldi Miq.?

Nom. Jap. Shirakawa-bōfū.

Ic. Jap. Somokuzusetsu, V. fol. 11.

Hab. In sylvaticis montanis Japoniae mediae et australis. Octobri fl. Prov. Ōmi: in monte Ibukiyama (K. Tsuji. Octobri fr.); Prov. Izumi: Hibaragoye (S. Matsuda); in monte Makioyama (K. Nagano); Prov. Kawachi: in monte Kongōsan (T. Tada. Octobri fl.); Prov. Harima; pago Kashimamura (U. Ogami); Prov. Izumo: in monte Sampeizan (Augusto): Prov. Tosa in ins. Shikoku: Shibakoku (T. Makino); in pago Kamibun (T. Makino. Decembri Fr.).

Distr. Korea: loco non indicato (Yenuma), Fusan, Chemulpo, Seule (T. Uchiyama).

6. P. cartilagino-marginatum Makino (in sched).

Caule erecto glabro supra ramoso, 2—2-pedali foliis bipinnatisectis, pinnis 2—3-jugis lanceolatis serrato-setulosis marginibus sublamelligeris petiolis superioribus vaginatis oblongis amplectentibus vaginis oblongis, involucris nullis vel oligophyllis deciduis; umbellis 8—15-radiatis, radiis angulatis intus scabris inæquilongis; involucelli foliolis paucis lanceolatis linearibus puberulis pedicellis brevioribus; umbellulis 10-v. multifloris, calycis dentibus obsoletis, petalis albis ovatis apice acutis involutis; antheris albis oblongis, fructibus jugis primariis dorsalibus æqualibus, vittis valleculae superficialibus, dorsalibus 1; lateralibus 2, commissuralibus 4 seminibus sectione subteretibus.

A. P. decursivo Maxim. differt caule graciliori, foliis minoribus segmentis foliorum angustioribus margine albo-lamerigeris serratis, vaginis oblongis nec saccato-orbiculatis, radiis umbellularum paucis.

Nom. Jap. Hosoba-Nodake

Hab. Kiushiu—Prov. Hizen: in monte Nishigatake; Prov. Higo: in vulcano Aso (ipse. Angusto fl.); Prov. Bungo: in campis Yubu, (Octobri-fl!).
Shikoku—Prov. Tosa (T. Makino).

Pastinaca L.

Pastinaca sativa L. rarius culta.

Heracleum L.

Linn. Gen. n. 345; Hoffm. Umb. I. p. 141; DC. Prodr. IV. p. 191; Endl. Gen Pl. no. 4477; Benth. et Hook. Gen. Pl. I. p. 921; Baillon Hist. d. Pl. VII. p. 205; Drude in Nat. Pfl. Fam. III. abt. VIII. p. 239.

Calycis lobi obsoleti v. parvi; petala inæqualia obcordata ob costam superne inflexa; stylopodia conica margine undulata, carpella a dorso plano compresso; juga dorsalia et intermedia tenuissima v. obsoleta, lateralia in alas expansa, vittae ad valleculas solitariae fructu breviores, carpophorum bi-partitum, semen plano compressum——Herba perennis altissima hirsuta; folia ampla latissime lobata v. ternatim dissecta, segmentis latis, umbella composita ∝-radiata, involucri foliola pauca caduca v. 0; involucella polyphylla, ovarium saepe pubescens.

Heracleum lanatum Michx. Fl. Bor. Am. I. p. 166; DC. Prodr. IV. p. 192; Hook, Fl. Bor. Am. I. p. 269; Ledeb. Fl. Ross. II. p. 328; A. Gray, Bot. Jap. p. 391; Maxim. Fl. As. Or. Frags. p. 23; Coult. Rose, Rev. N. Am. Umb. p. 48; Forbes et Hemsl. Ind. Fl. Sin. I. p. 336; Miyabe, Fl. Kurile Isl. p. 236;

Britton et Brown, Ill. Fl. N. st. Can. II. p. 514 ; Diels, Fl. Centr. China. Engl. Bot. Jahrb. XXIX. p. 503.

Heracleum barbatum Ledeb. Fl. Alt. I. p. 300 ; Fl. Ross. II. p. 322 ; Reg. et Til. Fl. Ajan. p. 98 ; Maxim. Prim. Fl. Amur. p. 129 ; Fr. Schmidt. Fl. Sach. p. 138 ; Fr. et Sav. Enum. Pl. Jap. I. p. 189.

H. Moellendorffii Hance in Journ. Bot. (1878) p. 12.

H. dissectum Ledeb. Fl. Alt. I. p. 301 ; Fl. Ross. II. p. 323.

Caule 3-multipedali sulcato ramoso tomentoso ; foliis 3—5-sectis, segmentis petiolulatis circumscriptione ovatis aut sub-orbiculatis 3—5-partitis inciso-lobatis, lobis serratis, serraturis acutis, apice acutis v. acuminatis superne glabriusculis subtus pubescentibus, petiolis superioribus late vaginatis; involucris 1—2-phyllis linearibus ; umbellis 14—20-radiatis ; involucellis 5—6-phyllis lineari-lanceolatis umbellulis florentibus brevioribus ; umbellulis multifloris, calycis marginibus obsoletis, petalis albis valde inæqualibus, apice bifidis ; staminibus petalis brevioribus, antheris albis stylis erectis petalis subæqualibus v. brevioribus ; fructibus immaturis hispidulis demum glabris obovatis valde a dorso compressis, jugis dorsalibus non obtectis, vittis dorsalibus 4, commissuralibus 2.

Nom. Jap. Hanaudo.

Icon. Jap. Honzōzufu, VII. fol. 19. recto ; Sōmokuzusetsu, V. fol. 36 ; Honzōkōmokukeimōzufu, IX. fel. 16 sub Sagaudo.

Hab. In collibus apricis et sylvaticis humidis per totam Japoniam, Maio fl. Junio fr. mat.

Kurile—Ins. Etorofu ad Furubetsu (sec. Miyabe). Ins. Shikotan (Herb. Kawakami).

Hokkaido (Yezo)—Prov. Ishikari : circa urbem Sapporo (Y. Tokubuchi) ; Prov. Kitami : in monte Rishiri (Herb. Kawakami).

Honshiu—Prov. Iwashiro (K. Nemoto) ; Prov. Shimotsuke : Osawa (Julio) ; Prov. Musashi : circa Tokyo, in monte Kobotoke (ipse) ; Prov. Yamashiro :

Arashiyama (K. Nagano); Prov. Ōmi: in monte Ibukiyama (K. Tsuji); Prov. Sagami: Yokoska (sec Franch.).
Shikoku—Prov. Iyo: in monte Ishizuchi.
Kiushiu—Prov. Higo: juxta Kumamoto (v. v.); Prov. Satsuma: Shiroyama; Ins. Tsushima: prope Izuhara (v. v.)

Observ. Spesimen unicum ex Ibukiyama, Prov. Ōmi foliis ternatis segmentis suborbiculatis 5-inciso-lobatis basi cordatis lobis inæqualiter crenatis subtus ad nervos pubescentibus prostat.

Distr. Sibiria, China septentrionali, Manchuria, Sachalin, Canada, America boreali.

Siler Scop.

Siler divaricatum Benth et Hook. Gen Pl. I. p. 909.
Nom. Jap. Bōfū. Saepe cultum.

Daucus L.

Daucus Carota L. Sp. Pl. ed. I. p. 242.
Nom. Jap. Ninjin.

Hab. Colitur. per totam Japoniam.

Distributio Umbelliferarum in imperio Japonico.

Species.	Kuril.	Yezo.	Honsiu Bor.	Honsiu Med.	Honsiu Aust.	Shikoku.	Kiusiu.	Liukiu.	Formosa.
Hydrocotyle javanica, Thunb.				—	—	—	—	—	—
„ conferta, Wight.									—
„ rotundifolia, Roxb.			—	—	—	—	—	—	—
„ Wilfordi, Maxim.	—	—	—	—	—	—	—		
„ ramiflora, Maxim.		—	—	—					
Centella asiatica, Urb.				—	—	—	—	—	—
Sanicula europæa, L.		—	—	—	—				
„ satsumana, Maxim.							—	—	
Anthriscus sylvestris, Hoffm.			—	—	—		—		
Osmoriza japonica, S. et Z.		—	—	—	—				
Torilis Anthriscus, Gmel.		—	—	—	—	—	—	—	—
Caucalis scabra, Makino.				—	—	—			
Pleurospermum austriacum, Hoffm.	—	—	—	*—					
Bupleurum falcatum, L.				—	—	—	—	—	—
„ sachalinense, Fr. Schm.	—	—	—	—					
„ multinerve, D C. var.		—	—	*—					
„ triradiatum, var. alpinum.		—							
Apium Ammi, Urb.							?		
Apodicarpum Ikenoi, Makino.				—					
Cicuta virosa, L.		—	—	—	—		—		
Cicuta nipponica, Franch.				—					
Cryptotaenia japonica, Hassk.		—	—	—	—	—	—	—	
Carum neurophyllum Fr. et Sav.				—			—		
„ holopetalum, Maxim.			—	—*	—*				
„ Tanakae, Fr. et Sav.				*—	*—	*—			
Chamæle tenera Miq.		—	—	—					
Aegopodium alpestre.	—	—	—						
„ Podagraria L.				?					
Pimpinella calycina, Maxim.	—	—	—	—	—	—	—		
„ serra, Fr. et Sav.				*—					
„ diversifolia, DC.				?			—		
„ sp.		—	—						
Nothosmyrnium japonicum, Miq.				—		—			
Sium Ninsi, L.			—	—	—		—		
„ nipponicum, Maxim.			—	—	......	—			
Œnanthe stolonifera, DC.	—	—	—	—	—	—	—	—	—
„ benghalensis, B. et. H.								—	—
„ linearis, Wall.									—
Seseli Libanotis Koch.		—	—	—	—				
„ Tachirœi, Fr. et Sav.				—					
Cnidium japonicum, Miq.			—	—	—	—	—		
„ longeradiatum, Max.					—	......	—		
„ ajanense, Drde.		—	—						
„ formosanum, m.									—

Distributio Umbelliferarum in imperio Japonico.

Species.	Kuril.	Yezo.	Honsiu Bor.	Honsiu Med.	Honsiu Aust.	Shikoku.	Kiusiu.	Liukiu.	Formosa.
Ligusticum scoticum, L.	—	—	—						
Ligusticum acutilobum, S. et Z.			—	—					
,, japonicum, Maxim.		—	—	—					
,, ibukiense, m.				—					
Cœlopleurum Gmelini, Ledeb.		—							
Cenolophium Fischeri ?	—								
Conioselinum univittatum, Turcz.	—	—	—						
Angelica anomala, Lallem.	—	—	—	*—					
,, ursina, Maxim.	—	—	—	*—					
,, refracta, Fr. Schm.	—	—							
,, edulis, Miyabe.	—	—	—						
,, kiusiana, Maxim.				—	—	·····	—	—	—
,, utilis, Makino.				—	—				
,, multisecta, Maxim.				—	—				
,, pubescens, Maxim.				—	—	—	—		
,, polyclada, Fr.			—	—					
,, shikokiana, Makino.						—			
,, nikoensis, m.				*—					
,, saxicola, Makino.						—			
,, Matsumuræ, m.				—					
,, sp.		—							
,, Florenti, Fr. et Sav.			*—	*—					
,, Miqueliana, Maxim.				—					
,, polymorpha, Maxim.			—	—	—	—	—		
,, hakonensis, Maxim.				—					
,, inæqualis, Maxim.					—	—			
Phellopterus littoralis, Fr. Schm.	—	—	—	—	—	—	—	—	
Peucedanum japonicum, Thunb.				—	—	—	—	—	
,, decursivum, Maxim.				—	—	—	—		—
,, terebinthaceum, Fisch.		—							
,, multivittatum, Maxim.				*—					
,, deltoideum, Makino.				—	—	—			
,, cartilagino-marginatum, Mk.						—	—		
Heracleum lanatum, Michx.	—	—	—	—	—	—	—		

* In montibus altis tantum occurit.

Distributio specierum quae cum florae Japonicae communes sunt.

GENERA.	Species Japon.	Species endemica.	Korea.	China.	Siberia.	Kamtschatka.	Sachalin.	India Or.	Australia.	America Bor.	Europa.	Africa Bor.
Hydrocotyle	5	1	1	2				3	1			1
Centella	1			1				1	1	1		1
Sanicula	2	1	1	1				1			1	1
Anthriscus	1 + 1?			1	1						1	1
Osmorhiza	1	1		1						1△		
Torilis	1		1	1	1			1			1	1
Caucalis	1	1										
Pleurospermum	1											
Bupleurum	4		1	1	2	1	1	1			1	
Apium	2 + 1 c	1							1	1		
Cicuta	2	1		1	1	1	1				1	
Cryptotaenia...	1	1		1						1△		
Carum	3 + 1 c.	2		1								
Ægopodium	3	1			1 + 1		1				1	
Pimpinella	4 + 1?	2		1				1				
Nothosmyrnium	1			1								
Sium	2 + 1?	2	1									
Seseli	2	1										
Oenanthe	3			2				3				
Cnidium...	4	2	1		1		1					
Ligusticum	4	2	1		1	1				1	1	
Cælopleurum	1				1	1	1			1		
Cenolophium	1				1							
Conioselinum	2	1?			1					1		
Angelica	20	1					3					
Phellopterus	1			1			1			1		
Peucedanum...	6	3	3	2	1							
Heracleum	1			1	1		1			1		

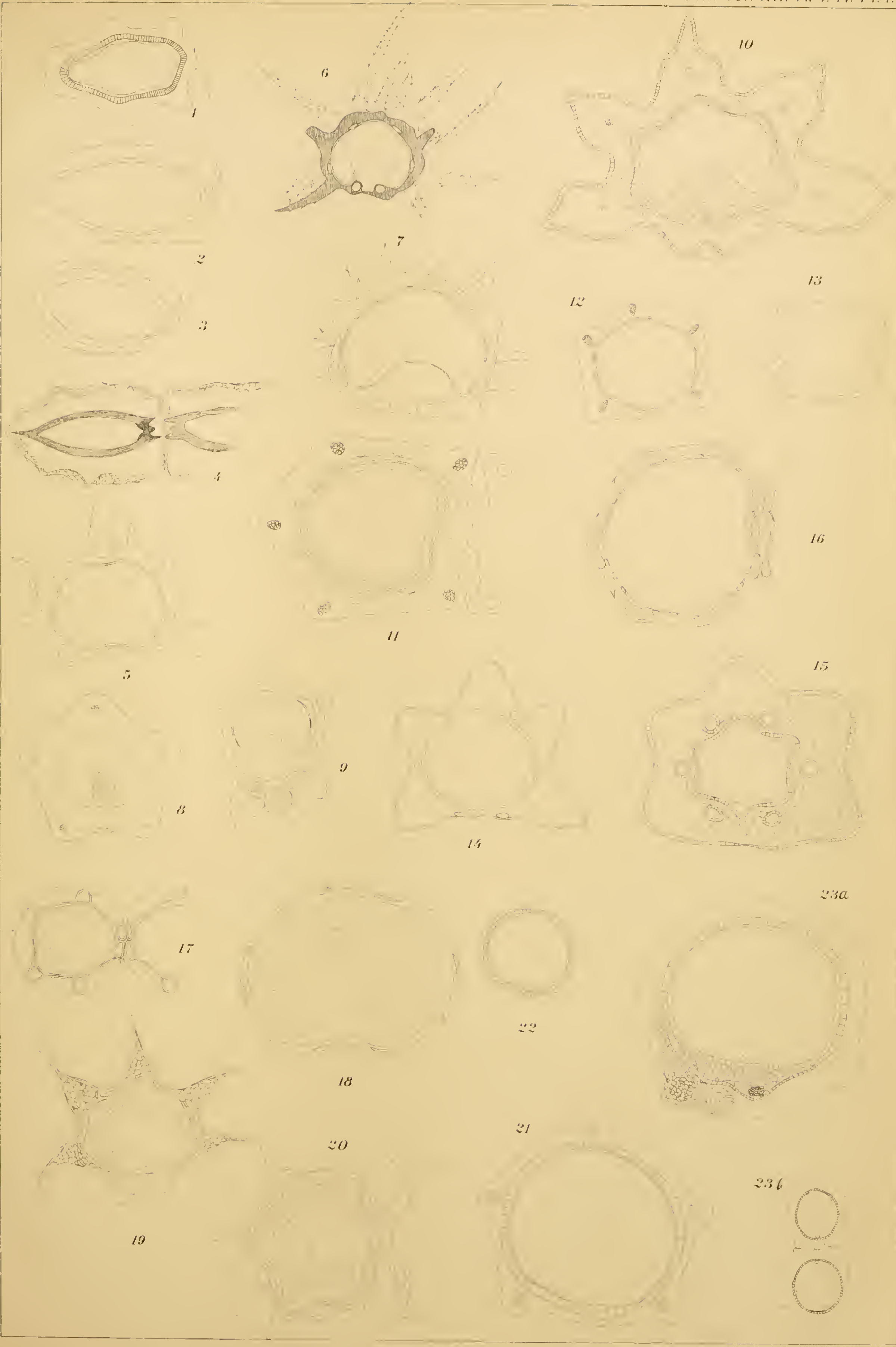
c. { Scandix 1. / Fœniculum 1. / Siler 1. }
c. { Coriandrum 1. / Anethum 1. / Daucus 1. }
c. { Conium 1. / Ferula 1. }
c. { Petroselinum 1. / Pastinaca 1. }

c. speciem cultam, △ speciem affinem significat.

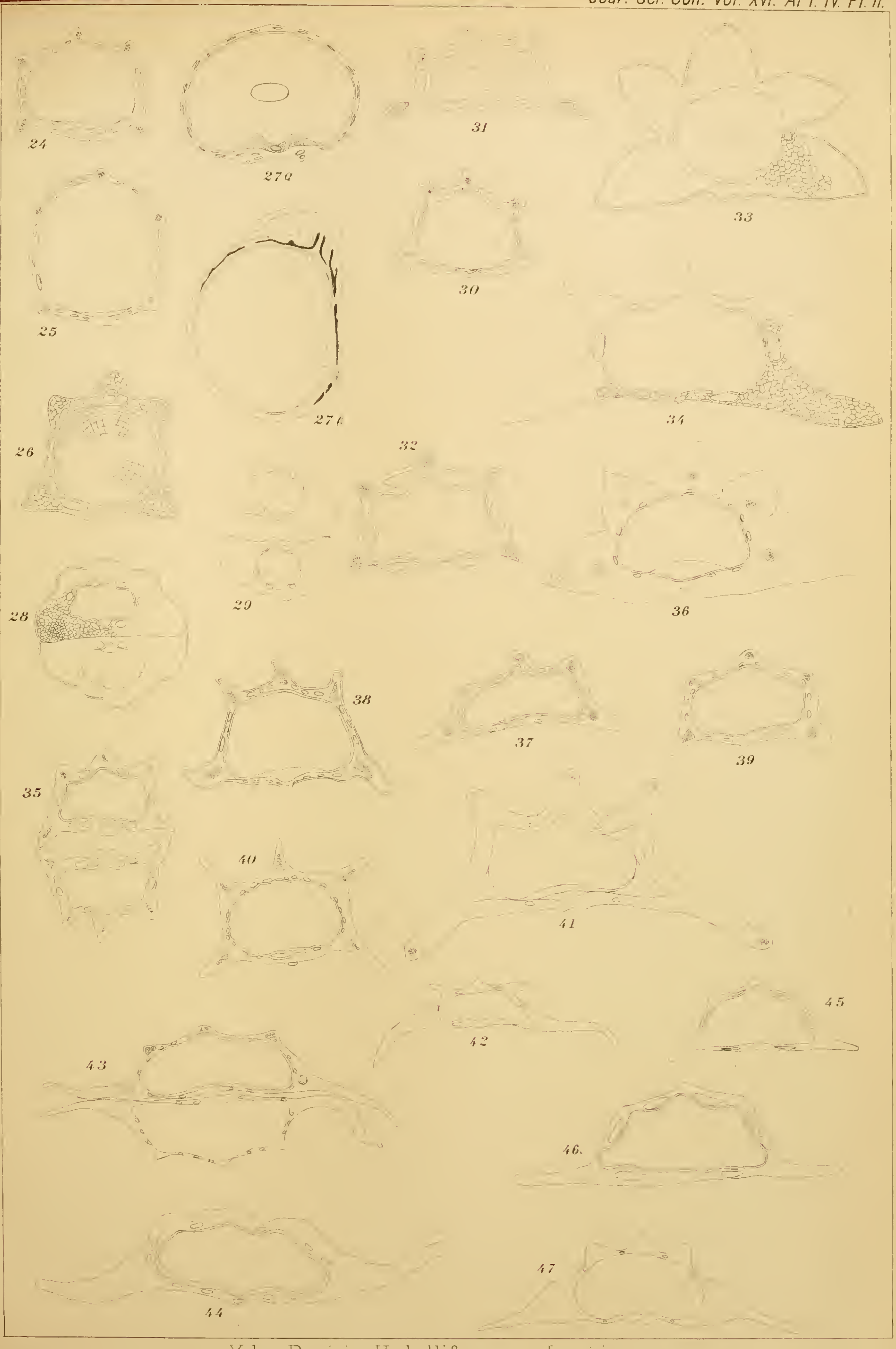
Index nominum specierum.

Fig. 1. Hydrocotyle Wilfordi Maxim.
2. " conferta Wight.
3. " rotundifolia Roxb.
4. Centella asiatica Urb.
5. Sanicula europaea L.
6. Caucalis scabra Makino.
7. Torilis anthriscus Bernh.
8. Osmorhiza japonica S. et Z.
9. Anthriscus sylvestris Hoffm.
10. Pleurospermum austriacum Hoffm.
11. Bupleurum sachalinense Fr. Schm.
12. B. falcatum L.
13. B. multinervis DC. var minor Ledeb.
14. Apium ammi Urb.
15. A. (Apodicarpum) Ikenoi Makino.
16. Cryptotaenia japonica Hassk.
17. Cicuta virosa L.
18. Carum Tanakae Fr. et Sav.
19. C. neurophyllum Maxim.
20. C. holopetalum Maxim.
21. Aegopodium alpestre Ledeb.
22. Chamale tenera Miq.
23. " " "
24. Pimpinella diversifolia Dc.
25. P. calycina Maxim.
26. Sium nipponicum Maxim.
27. Nothosmyrnium japonicum Miq.
28. Oenanthe stolonifera DC.
29. Oenanthe benghalensis B. et H.
30. Seseli Libanotis L.
31. Fœniculum vulgare L.
32. Anethum graveolens L.
33. Cnidium japonicum Miq.

Fig. 34. Cnidium formosanum m.
35. " ajanense Drude.
36. Coelopleurum Gmelini Ledeb.
37. Ligusticum japonicum Maxim.
38. " scoticum L.
39. " acutilobum S. et Z.
40. " ibukiense m.
41. Cenolophium Fischeri Turcz.
42. Conioselinum univittatum Turcz.
43. Angelica pubescens Maxim. var.
44. A. Matsumurae m.
45. A. shikokiana Makino.
46. A. nikoensis m.
47. A. Florenti Maxim.
48. A. anomala Lallen.
49. A. pubescens Maxim.
50. A. kiusiana Maxim.
51. A. utilis Makino.
52. A. hakonensis Maxim.
53. A. ursina Maxim.
54. A. inæqualis Maxim.
55. A. edulis Miyabe.
56. A. Miqueliana Maxim.
57. A. Polymorpha Maxim.
58. Phellopterus littoralis Fr. Schm.
59. Peucedanum decursivum Maxim.
60. Peucedanum cartilaginomarginatum Makino.
61. P. japonicum Miq.
62. P. terebinthaceum Fisch.
63. P. deltoideum Makino.
64. Ferula communis L.
66. Heracleum lanatum Michx.
67. Peucedanum multivittatum Maxim.



Yabe: Revisio Umbelliferarum Japonicarum.



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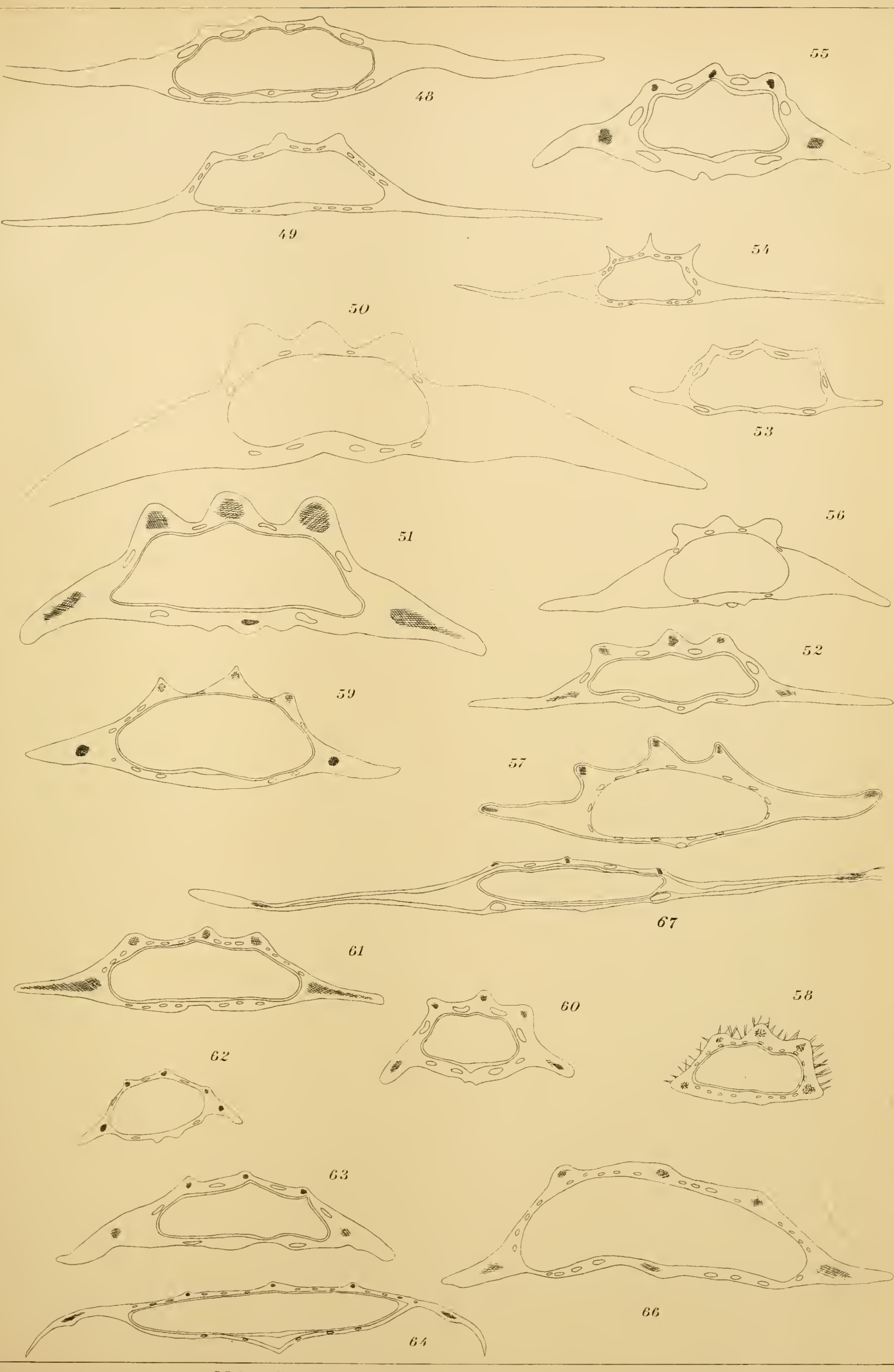
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JOURNAL OF THE COLLEGE OF SCIENCE, IMPERIAL UNIVERSITY,
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Revisio Alni Specierum Japonicarum.

Auctore

Dr. J. MATSUMURA,

in Universitate imperiali Tokyoensi botanices Professor.

Cum tabulis 4.

Alnus *Tournef.*

§ 1. *Alnaster* Endl.

1. **Alnus viridis,** DC. var. **sibirica,** Regel in DC. Prodr. XVI. 2. p. 182; Fr. et Sav. Enum. Pl. Jap. I. p. 456; Miyabe, Fl. Kurile Isl. p. 259; Herd. Pl. Radd. in Act. Hort. Petrop. XII. p. 70.

Alnaster fruticosus, Ledeb. Fl. Ross. III. p. 655; Regel et Tiling, Fl. Ajan. p. 119; Trautv. in Maxim. Prim. Fl. Amur. p. 257; Fr. Schm. Fl. Sachal. p. 175.

Alnus viridis lus. a et c, et γ. *suaveolens,* Regel, Monogr. Betul. p. 79–81; Regel, Bemerk. p. 422.

Arbor 10-pedalis; truncus circuitu 2-ped. Ramuli angulati glabri, cortice griseo vel brunneo lenticellis oblongo-ellipticis vel

subrotundatis instructo. Folia ovalia vel oblongo-elliptica acuta, basi oblique subcordata subsimpliciter arguteque dentata, supra glabra subtus glutinoso-punctulata, in axillis venarum pubescentia, ad venam mediam glabra vel parce hirtella; juvenilia glutinosa, subtus ad venam mediam petiolumque punctulata. Stipulae elliptico-oblongae glabrae. Amenta feminea plerumque 4, in racemos disposita; pedunculi hirtelli punctulatique. Strobili ellipsoidei. Nuculae ellipticae pallidae ala membranacea cinctae, alis sursum latioribus nuculae latitudinem subaequantibus vel iis duplo triplove angustioribus.

Folia supp. maxima 9½ cm. longa, 9 cm. lata. Petioli 25 mm. longi. Strobili 9–15 mm. longi, 6 mm. lati. Nuculae alis inclusis 2–3 mm. longae, 3 mm. latae.

Hab. in regionibus alpinis—

Kurile: ins. Urupp, loco Perikamoi dicto leg. K. Uchida anno 1891.

Yezo: prov Ishikari, ad Sapporo leg. Y. Tokubuchi anno 1892; Jōzankei ejusdem prov. (ipse) anno 1899; prov. Shiribeshi, loco Okushiri dicto leg. K. Miyabe et Y. Tokubuchi anno 1890; prov. Ojima, Fukuyama leg. K. Miyabe et Y. Tokubuchi anno 1890; Morolan ejusdem prov. (ipse) anno 1899; monte Komagatake ejusdem prov. leg. R. Yatabe anno 1877.

Hondō: prov, Mutsu, prope Aomori leg. T. Iwakawa anno 1880; prov. Ugo, monte Chōkaisan leg. S. Ōkubo et R. Yatabe anno 1887; prov. Uzen, monte Gassan leg. S. Okubo et R. Yatabe anno 1887; prov. Iwashiro, prope Aizu leg. R. Yatabe et (ipse) anno 1879; prov. Shimotsuke, montibus Nantaisan et Shiranesan (ipse) anno 1885; prov. Rikuzen, monte Kattadake leg. Y. Yabe anno 1898; prov. Suruga, monte Fuji leg. R. Yatabe et (ipse) anno 1881; prov. Etchū, monte Tateyama leg. R. Yatabe et (ipse) anno 1884.

2. **Alnus Sieboldiana,** Nob.

Alnus firma, Sieb. et Zucc. Fl. Jap. Fam. Nat. II. p. 229; Regel, Monogr. Betul. p. 84, t. XV. fig. 1–9; Miq. Prol. p. 69 (pro parte).

Alnus firma, var. *a. typica*, Regel in DC. Prodr. XVI. 2. p. 183; Regel Bemerk. p. 423; Fr. et Sav. Enum. Pl. Jap. I. p. 457; Prantl in Engl. et Prantl, Nat. Pflanzenf. III. Teil, I. abteil. p. 45 (pro parte).

Arbor usque 10-pedalis. Ramuli glabri vel subverrucosi, cortice griseo lenticellis rotundatis instructo. Gemmae ovoideae, sessiles vel substipitatae, stitipitibus verrucosis. Folia late ovata acuminata, basi oblique rotundata, supra glabra vel glabriuscla sub lente inter costas secundarias parce adpresseque strigillosa, subtus ad venas hirtella vel pilosula vel glabro-punctulata, in axillis venarum barbulata, inaequaliter dentata, utrinque 14-15-costata; petioli subglabri. Stipulae oblongae glabrae. Amenta feminea e gemma singula solitaria; pedunculi plus minus hirtello-verrucosi; fructiferi saepius glabri. Amenta mascula 3-6 lateralia rarius terminalia secus ramulos in racemos disposita. Squamae fl. mas. ovales subacutae apice emarginulatae, margine nudae, utrinque punctulatae, 3-florae, 3-bracteolatae, bracteolis ellipticis vel oblongis obtusissimis. Flores 4-andrae. Perianthium 4-partitum; segmenta inaequalia, 2 anterioribus ovalibus, 2 posterioribus oblongo-ellipticis, denticulatis glanduliferis enervis. Antherae flavescentes, ovales vel late ellipticae, thecis sejunctis; filamenta perianthii segmenta subsuperantia. Strobili ellipsoidei, subglobosi. Squamae juveniles oblongo-cuneatae; adultae cuneatae versus basin attenuatae, intus 5-sulcatae. Nuculae pallidae subrhomboideae ala membranacea cinctae, alis sursum latioribus nuculae latitudinem subaequantibus vel iis latioribus.

Foliorum lamina supp. maxima $12\frac{1}{2}$ cm. longa, usque 8 cm. lata.

Petioli 15-20 mm. longi. Stipulae 21 mm. longae, 6 mm. latae. Strobili 26 mm. longi, 15 mm. lati ; pedunculi 12-27 mm. longi. Squamae 8 mm. longae, 6 mm. latae. Nuculae vix 4 mm. longae. Amenta mascula 3-6 cm. longa, 11. mm. lata.

Hab. in maritimis ad meridiem—

Hondō ; prov. Musashi, pago Koyasu dicto leg. T. Makino anno 1895 ; prov. Sagami, ad Yokosuka (ipse) anno 1880 ; jugo Hakone (ipse) ; ad Misaki et Arai ejusdem prov. leg. Y. Yabe anno 1998 ; prov. Izu, ad Shimoda leg. K. Saida anno 1886 ; in pago Tani dicto leg. S Ōkubo anno 1883 ; ins. Ōshima et Kōzu, et monte Mihara ejusdem prov. leg. S. Ōkubo anno 1887 ; ad Yugashima ejusdem prov. leg. C. Ōwatari anno 1895.

3. **Alnus Yasha**, Nob.

Alnus firma, Sieb. et Zucc. Fl. Jap. Fam. Nat. II. p. 229 ; Regel in DC. Prodr. XVI. 2, p. 183 ; Regel, Bemerk. p. p. 423 ; Fr. et Sav. Enum. Pl Jap. I. p. 457 (pro parte).

Alnus firma, var. *hirtella*, Fr. et Sav. l. c. et II. p. 502 (pro parte.)

Alnus harinoki, Sieb. Syn. Pl. Oeconom. p. 25.

Betula Alnus, Thunb. Fl Jap. p. 76.

Ōba-minebari, Sōmoku-zusetsu. Arb. ined. VII. t. 83 (figura mala).

Arbor usque 10-pedalis. Ramuli juveniles dense hirtelli ; adulti glabri, cortice brunneo vel griseo-brunneo. Gemmae ovoideae acutae glabrae. Folia ovato-vel oblongo-lanceolata acuta, basi oblique subrotundata vel acuta, supra inter costas secundarias adpresse strigillosa, subtus ad venas medias secundariasque hirtella interdum in axillis venarum barbulata, punctulata glutinosa vel epunctata, subinaequaliter minuteque dentata, utrinque 14-17-costata ; petioli semper

hirtelli. Stipulae ovatae vel oblongae, subcordatae glabrae, petiolos superantes. Amenta mascula terminalia. Squamae fl. mas. ovales vel. late ovatae obtusae, margine ciliolatae, triflorae, 2-3-bracteolatae, bracteolis obovato-ellipticis vel ovalibus, apice emarginatis ciliolatis. Flores 5-6-andrae. Perigonium 4-5-partitum, segmentis inaequalibus, ellipticis obtusis, obovato-ovalibus, rotundato-cuneatis retusis prominente nervosis, margine glanduliferis. Antherae flavescentes, late ovales; filamenta perianthii segmenta aequantia. Strobili ellipsoidei vel oblongi, ad ramulos subterminales, solitarii vel subracemosi; squamae rite cuneatae retusae, intus 4-costatae. Nuculae ellipticae utrinque acutae ala membranacea cinctae, alis sursum ampliatis. Pedunculi fructiferi hirtello-verrucosi vel subglabri. Foliorum lamina $11\frac{1}{2}$ cm. longa, $4\frac{1}{2}$ cm. lata. Petioli 7-15 mm. longi. Pedunculi 23 mm. longi. Squamae fl. mas. 2 mm. latae. Strobili 16-25 mm. longi, 15 mm. lati. Squamae strobilorum 5-7 mm. longae, 5 mm. latae. Nuculae 3 mm. longae et latae.

Hab. in sylvis montanis ad septentrionem –

Hondō: prov. Rikuzen, monte Kattadake leg. K. Miyajima anno 1894; prov. Iwashiro, in tractu Aizu leg. R. Yatabe et (ipse) anno 1879; prov. Iwaki, loco Tomioka dicto leg. S. Ikeno; prov. Shimotsuke, in montibus Nikkō leg. K. Sawada et R. Yatabe anno 1879; prov. Musashi, in tractu Chichibu leg. (ipse) anno 1878; prov. Shinano, monte Asama leg. R. Yatabe et (ipse) anno 1880 et Y. Yabe anno 1896; prov. Hitachi, monte Hanazono leg. (ipse); prov. Sagami, in tractu Hakone leg. R. Yatabe et (ipse) anno 1881; prov. Kawachi, monte Kongōsan leg. T. Tada anno 1899.

Shikoku: prov. Tosa, monte Yahazu leg. T. Makino anno 1888.

Kiushiu: prov. Hyuga, monte Kirishima leg. R. Yatabe et

(ipse) anno 1882; prov. Higo, monte Aso leg. Y. Yabe anno 1901; prov. Ōsumi (sec. Tanaka*).

4. **Alnus pendula**, Nob.

Alnus firma, var, *multinervis*, Regel in DC. Prodr. XVI. 2, p. 183; Regel Bemerk. p. 423; Miq. Prol. p. 358; Fr. et Sav. Enum. Pl. Jap. I. p. 457 (pro parte).

Minebari, Sōmoku-zusetsu, Arb. ined. VII. v. 79.

Arbor parva. dumosa, 7-8-pedalis. Ramuli juveniles hirtelli, cortice brunneo-nigricanti lenticellis oblongis, linearibus vel subrotundatis instructo. Gemmae ovoideae acutae glabrae. Folia oblongo-lanceolata acuminata vel ovato-oblonga acuta, basi subobliqua vulgo acuta rarius subrotundata, supra inter costas secundarias adpresse strigillosa, subtus ad venas medias secundariasque hirtella, inaequaliter dentata, utrinque 13-27-costata, reticulis interjectis subprominulis vel obscuris, in axillis venarum barbulata, glutinosa; petioli hirtelli. Stipulae oblongo-lineares oblongae subacutae vel obtusae petiolos superantes. Amenta mascula ...... Amenta feminea terminalia lateraliave e gemma singula 2-5 in racemos disposita; racemus pendulus; pedunculi graciles sursum subquadrangulares hirtelli. Strobili parvi ellipsoidei. Squamae cuineiformes intus extusque sursum tomentosae, postice 4-costatae. Nuculae pallidae ellipticae vel obovato-ellipticae utrinque acutae glabrae, ala membranacea cinctae, alis sursum ampliatis retusis vel obcordatis nuculae latitudinem subaequantibus. Foliorum lamina 12 cm. longa, 4 cm. lata. Petioli 2-8 mm. longi. Racemi 5-6½ cm. longi. Pedunculi 10-23 mm. longi. Strobili 6-14 mm. longi, 8-9 mm. lati. Nuculae 3 mm. longae, sursum alis inclusis vix 3 mm. latae. Squamae 3 mm. longae, 5 mm. latae.

* Dai-Nippon Shokubutsu-tai Chōsa-Hōkoku, 1885, p. 19.

Hab. in regionibus subalpinis, vulgo ad margines rivulorum—

Yezo : prov. Ojima, loco Yoshioka-sandō dicto leg. K. Miyabe et Y. Tokubuchi anno 1890 ; prov. Ishikari, loco Jōzankei dicto (ipse) anno 1899 ; prov. Shiribeshi (sec. Sugiyama.)

Hondō : prov. Mutsu, planis Tokiwano dictis leg. T. Iwakawa anno 1880 ; prov. Uzen, loco inter montes Gassan et Hagurosan leg. S. Ōkubo et R. Yatabe anno 1887 ; prov. Rikuzen, regione montana Aone dicta leg. K. Miyajima anno 1894 ; prov. Echigo, monte Gozu et pago Deyumura leg. S. Ōkubo et R. Yatabe anno 1886 ; prov. Kaga, ad pedem montis Hakusan leg. R. Yatabe et (ipse) anno 1881.

§ 2. *Gymnothyrsus* Spach.

5. **Alnus maritima,** Nutt. Sylv. Am. Suppl. I. p. 34. t. 10. var. **japonica,** Regel in DC. Prodr. XVI. 2, p. 186 ; Regel Bemerk. p. 428 ; Miq. Prol. p. 358 ; Fr. et Sav. Enum. Pl. Jap. I. p. 457 ; Burkill in Journ. Linn. Soc. Bot. XXVI. p. 500 ; Palib. Consp. Fl. Kor. II. p. 48.

Alnus maritima, var. *arguta*, Regel in DC. Prodr. XVI. 2. p. 186 ; Regel Bemerk. p. 428 ; Fr. et Saw. Enum. Pl. Jap. I. p. 458 ; Herd. in Act. Hort. Petrop. XII. p. 73.

Alnus maritima, var. *minor*, Miq. Prol. p. 358.

Alnus japonica, Sieb. et Zucc. Fl. Jap. Fam. Nat. II. p. 230 ; Regel, Monogr. Betul. p. 85, t. 16, fig. 22-27 ; Miq. Prol. p. 69 ; Sarg. Forest Fl. Jap. p. 63, pl. 20 ; Shirasawa, Nippon Shinrin Jumoku-zufu, t. 19, fig. 18-34.

Alnus japonica, var. *minor*, Miq. Prol. p. 69.

Harinoki vel *Han-no-ki*, Sōmoku-zusetsu, Arb. ined. VII. t. 75.

Arbor magna usque 20-30-pedalis alta ; truncus circuitu 6-7-ped. Ramuli juveniles angulati glabri vel puberuli. Folia longe petiolata, elliptico-oblonga, oblonga acuta saepe obtusa, basi acuta vel subrotun-

data, supra glabra vel parce puberula, utrinque punctulata vel rarius epunctata, in venarum axillis barbulata vel nuda, margine subundulata minute arguteque serrata; petioli glabri vel pubescentes. Amenta mascula terminalia, 1-6 subracemosa, foliis praecociora. Amenta feminea 2-6 secus ramulos in racemos disposita. Strobili ellipsoidei vel ovoideo-ellipsoidei interdum subglobosi. Squamae flabellato-cuneatae intus multicostatae. Nuculae fuscae suborbiculares vel obovato-ellipticae glabrae rarius pubescentes, ala angustissima cinctae.

Strobili 15-25 mm. longi, 10-15 mm. lati. Squamae 6-7 mm. longae, 6-8 mm. latae. Nuculae 3-5 mm. longae, 3-3½ mm. latae.

Hab. in humidis planis—

Yezo: prov. Ishikari, circa urbem Sapporo leg. K. Miyabe et. Y Tokubuchi anno 1891; loco non indicato leg. Boehmer et S. Hori; ad pedem montis Moiwa (ipse) anno 1899; prov. Ojima, prope Hakodate leg. R. Yatabe anno 1877.

Hondō: prov. Mutsu, planis Takiwano dictis leg. T. Iwakawa anno 1880; pago Kawaguchi prope Awomori leg. H. Shirasawa; prov. Iwashiro, tractu Aizu leg. R. Yatabe et (ipse) anno 1879; prov. Hitachi, ad pedem montis Tsukuba leg. C. Ōwatari anno 1895; prov. Musashi. circa urbem Tokyō (ipse) anno 1879; prov. Sagami, ad Yokosuka (ipse) anno 1880; prov. Izumi, monte Ushitakisan leg. S. Matsuda anno 1895.

Kiushiu: prov. Chikuzen. leg. K. Nagano.

var. **formosana**, Burkill in Journ. Linn. Soc. Bot. XXVI. p. 500.

Alnus maritima, var. *japonica*, Regel in DC. Prodr. XVI. 2, p. 186 (pro parte).

Alnus maritima, Henry in Trans. Asiat. Soc. Jap. XXIV. Suppl. p. 90.

Ramuli angulati punctulati, cortice cinereo-fusco lenticellis rotundatis vel ellipticis instructo. Folia elliptica oblonga vel oblongo-lanceolata obtusa, acuta vel acuminata, basi plerumque acuta rarius subrotundata. utrinque glabra punctulata, margine minute serrata. Amenta in ramis foliiferis coaetanea producta. Amenta mascula 2-5. Strobili ellipsoidei, 2-6 in racemos dispositi. Squamae intus multicostatae. Naculae fuscae, ellipticae, rhomboideae. ala angustissima coriacea marginatae.

Foliorum lamina 12 cm. longa, 5½ cm. lata. Strobili 18 mm. longi, 10 mm. lati. Squamae 4 mm. longae et latae. Nuculae 3 mm. longae, 2 mm. latae.

Hab. in Formosa : loco Shinkanshō dicto leg. C. Ōwatari anno 1897 ; loco Shinchik dicto leg. Hiraoka anno 1897 ; loco non indicato leg. S. Honda, Konishi et Yae ; tractu Gilanchoo leg. K. Miyake anno 1899.

Nom. Sinico-Formos. *tsui-koo-ah* (水柯仔) v. *shui-lyū-koh* (水流柯).

6. **Alnus glutinosa,** Willd. Sp. Pl. IV. pars 1, p. 334, var **japonica,** Nob.

Alnus glutinosa, Miq. Prol. p. 69.

Alnus maritima, var. *obtusata*. Fr. et Sav. Enum. Pl. Jap. I p. 458.

Meharinoki, Sōmoku-zusetsu, Arb. ined. VII. t. 77.

Arbor parva. Rami glabri, cortice cinereo-fusco lenticellis rotundatis prominulis instructo. Ramuli juveniles glutinosi saepe verrucosi. Folia obovato-elliptica obtusissima mucronulata rarius acuta vel emarginata, basi acuta vel rotundata, margine subundulata minutissime denticulata, supra glabra, subtus in venarum axillis barbu-

lata vel ad venas puberula, utrinque 6-10-costata, costis suberecto-patentibus; juvenilia glutinosa. Stipulae ampliatae ellipticae, obtusae. Strobili adulti ellipsoidei; juveniles oblongi. 2-4 in racemos dispositi. Squamae spatulatae, abrupte angustatae quasi stipitatae intus 4-costatae. Nuculae fuscae, rotundatae vel obovatae saepe verrucosae, ala angustissima marginatae. Foliorum lamina maxima 10 cm. longa, 8-9 cm. lata. Petioli vix 1½ cm. longi. Squamae 5 mm. longae, vix 3 mm. latae.

Hab. in regionibus planis et submontosis. vulgo ad margines fluminum, ad meridiem—

Hondō: prov. Etchū, ad pedem montis Tateyama leg. R. Yatabe et (ipse) anno 1884; prov. Shinano, ad pedem montis Togakushi leg. R. Yatabe et (ipse) anno 1884; prov. Yamato, ad margines fluminis Yamato leg. S. Ōkubo et (ipse) anno 1883; prov. Yamashiro leg. T. Makino anno 1894.

Shikoku: prov. Iyo, tractu Kami-ukina leg. H. Shirasawa anno 1897; prov. Tosa leg. R. Yatabe anno 1887; pago Ōkubo ejusdem prov. leg. R. Yatabe anno 1887.

7. **Alnus incana,** Willd. Sp. Pl. IV. p. 335. var. **glauca,** Ait. Hort. Kew. ed. 2, p. 259; Willd. l.c. p. 335; Regel, Monogr. p. 96, t. 16. fig. 19-20; Regel in DC. Prodr. XVI. p. 189; Regel. Bemerk. p. 433; Miq. Cat. Mus. Bot. Lugd.-Bat. p. 84; Fr. et Sav. Enum. Pl. Jap. I. p. 458; Palib. Consp. Fl. Kor. II. p. 48.

Alnus incana, var. *glabrescens*, Spach, Rev. Betul. p. 206.

Alnus incana, var. *hirsuta*, Miq. Prol. p. 69; Miyabe, Fl. Kurile Isl. p. 259; Matsudaira in Tokyo Bot. Mag. X. p. 469.

Yama-harinoki, Sōmoku-zusetsu, Arb. ined. VII. t. 81; H. Shirasawa, Nippon Shinrin Jumoku-zufu. t. 19, fig. 1-17.

Arbor magna ultra 10-pedalis; truncus circuitu 5-6 ped. metiens. Ramuli angulati glabri, cortice fusco vel cinereo-fusco lenticellis rotundatis ellipticis vel oblongis instructo; ramuli annotini saepius pubescentes. Gemmae obovoideo-ellipsoideae vel subglobosae saepius pubescentes. Folia laete viridia ambitu rotundata, late elliptica, apice rotundata obtusa vel acuta, basi rotundata, subcordata retusa vel oblique subacuta, margine duplicato-serrata vel dentata vel lobulata: juvenilia tomentosa, adulta supra glabrescentia vel pilosula, subtus pubescentia, puberula vel glabrescentia, glauca punctulata, vel ad venas pubescentia rarius in venarum axillis barbulata. Stipulae ellipticae oblongae obtusae vel subacutae, glabrescentes vel puberulae. Strobili ellipsoidei vel ovoideo-ellipsoidei, 2-5 in racemos dispositi. Squamae flabellato-cuneatae intus 4-costatae. Nuculae fuscae, late obovato-ellipticae vel elliptico-cuneatae, ala angustissima coriacea cinctae.

Foliorum lamina usque $9\frac{1}{2}$ cm. longa, $11\frac{1}{2}$ cm. lata. Petioli $3\frac{1}{2}$ cm. longi. Strobili 26 mm. longi, 13 mm. lati. Nuculae 4 mm. longae et latae.

Hab. in regionibus montosis, vulgo humidis vel ad margines fluminis—

Yezo: Kurile, ins. Shikotan leg. T. Kitahara; prov. Ishikari, pago Hiragishi prope Sapporo (ipse) anno 1899.

Hondō: prov. Mutsu, pago Kurauchi-mura leg. H. Shirasawa anno 1895; prov. Rikuzen loco Ōban-daira dicto leg. Y. Yatabe anno 1898; prov. Shinano monte Togakushi leg. R. Yatabe et (ipse) anno 1884; prov. Suruga monte Fuji (ipse) anno 1881; prov. Shimotsuke montibus Nikkō (ipse) anno 1889; Shiobara ejusdem prov. (ipse) anno 1891; prov. Musashi (ipse) anno 1893; prov. Sagami, Yokosuka (ipse) anno 1880.

Shikoku: prov Tosa, monte Kuromori leg. R. Yatabe anno 1888; prov. Iyo; prov. Awa (sec. J. Tanaka*).

var. **hirsuta**, Spach, Rev. Betul. p. 207; Ledeb. Fl. Ross. III. p. 656; Trautv. in Maxim. Prim. Fl. Amur. p. 258; Regel, Monogr. p. 97; Regel. Bemerk. p. 433; Regel in DC. Prodr. XVI. 2. p. 189.

Ramuli subteres tomentosi; rami glabrescentes, cortice cinereo-fusco lenticellis rotundatis prominulis instructo. Gemmae obovoideo-ellipsoideae vel ovoideae utrinque subacutae, viscosae. Folia pallide viridia, siccitate ferrugineo-fuscentia, plerumque subrotundata vel elliptica, obtusa vel acutiuscula, basi oblique rotundata vel subacuta, duplicato-dentata, supra parce adpresso-subpilosula vel subpuberula vel glabrescentia, subtus tomentosa, utrinque 9-11-costata, costis suberecto-patentibus; petioli tomentosi. Strobili ellipsoidei vel oblongi, 3-4 in racemos dispositi. Squamae intus 4-costatae. Nuculae fuscae ellipticae, ala angustissima marginatae.

Foliorum lamina 8½ cm. longa et lata (in forma parvifolia in Hondō lecta, 4½ cm. longa et lata). Strobili 5-19 mm. longi, 7-8 mm. lati.

Hab. in regionibus montuosis, ad septentrionem—

Yezo: prov. Ishikari, loco Tsukisapp dicto leg. K. Miyabe anno 1894; pago Hiragishi ejusdem prov. (ipse) anno 1899.

Hondō: prov. Mutsu. monte Osorezan leg. H. Shirasawa anno 1897; in montibus inter prov. Kōzuke et Iwashiro leg. H. Shirasawa anno 1895; prov. Kōzuke, tractu Tone-gōri leg. H. Shirasawa anno 1895; prov. Shimotsuke, montibus Nikko (ipse) anno 1886.

var. **sibirica**, Led. Fl. Ross. III. p. 656; Spach, Rev. Betul. p. 207; Regal, Monogr. Betul. p. 98; Regel in DC. Prodr. XVI. 2, p. 189; Regel, Bemerk. p. 434.

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* l.c. p. 19.

Ramuli angulati glabri, cortice griseo lenticellis rotundatis ellipticis vel oblongis prominulis instructo. Gemmae obovoideo-ellipsoideae. Folia juvenilia utrinque subhirsuta vel tomentosa; adulta glabrescentia, supra pilosula, subtus ad venas tantum puberula saepe punctulata, ambitu ovalia elliptica apice rotundata acuta, basi rotundata subcordata vel subacuta simpliciter serrata vel denticulata vel subduplicato-dentata, utrinque 10-12-costata, costis erecto-vel subarcuato-patentibus. Strobili immaturi ellipsoidei vel oblongi, 2-5 in racemos dispositi.

Foliorum lamina $11\frac{1}{2}$ cm. longa, 9 cm. lata. Ptioli usque 20 cm. longi. Strobili immaturi 9-18 mm. longi.

Hab. in regionibus montanis, ad septentrionem—

Yezo : loco non indicato, leg. K. Miyabe.

Hondō : prov. Mutsu, tractu Shimokita-gōri, pago Kawauchi-mura leg. H. Shirasawa anno 1895.

var. **emarginata**, Nob.

Alnus glutinosa, Matsum. List Pl. Nikkō, (1894) p. 29, non Willd.

Arbor mediocris. Ramuli subangulati, glabri punctulati, cortice cinereo-fusco lenticellis plerumque rotundatis instructo. Gemmae ellipsoideae acutae vel obtusae. Folia late elliptica, rotundato-elliptica, basi acuta vel oblique subrotundata, apice profunde emarginata excisa, subduplicato-dentata; juvenilia pilosula, adulta supra parce pilosula vel glabrescentia vel glabra, subtus glauca punctulata, ad venas axillasque venarum puberula, utrinque 7-9-costata, costis suberecto-patentibus. Strobili ellipsoidei, 2-4 in racemos dispositi. Squamae flabellato-cuneatae intus sulcatae. Pedunculi rigidi; pedicelli brevissimi. Nuculae fuscae, obovato-ellipticae nec orbiculares, ala angusta membranacea cinctae.

Foliorum lamina 9 cm. longa, 7 cm. lata. Petioli usque 3 cm.

longi, pilosiusculi. Strobili 17 mm. longi, 12 mm. lati. Nuculae 3 mm. longae, vix. 3 mm. latae. Squamae 6-7 mm. longae et latae.

Hab. in regionibus alpinis—

Hondō : prov. Shimotsuke, monte Konseitōge (ipse) anno 1885 ; monte Nyohōsan leg. Y. Yatabe et (ispe) anno 1901 ; prov. Kōtsuke, monte Shimizutōge leg. K. Watanabe anno 1894.

Alni specierum distributio in Imperio japonico.

Species et varietates.	*Kurile.*	*Yezo.*	*Hondō.*	*Ōshima.* (ins. adjac. prov. Izu)	*Shikoku.*	*Kiushiu.*	*Liukiu.*	*Formosa.*
Alnus viridis, var. sibirica.				—	—	—	—	—
Alnus Sieboldiana.	—	—			—	—	—	—
Alnus Yasha.	—	—		—			—	—
Alnus pendula.	—				—	—	—	—
Alnus maritima, var. japonica. ...	—				—		—	—
Alnus maritima, var. formosana. ...	—	—	—	—	—	—	—	
Alnus glutinosa, var. japonica.	—	—		—		—	—	—
Alnus incana, var. glauca.				—		—	—	—
Alnus incana, var. hirsuta.	—			—	—	—	—	—
Alnus incana, var. sibirica.	—			—	—	—	—	—
Alnus incana, var. emarginata. ...	—	—		—	—	—	—	—

Tabularum Explicatio.

Tabula I.

Fig. 1. **Alnus Sieboldiana**: rami fructiferi in magnitudine naturali.

Fig. 2. Squama strobili $^5/_1$ aucta, antice visa.

Fig. 3–4. Nuculae $^5/_1$ auctae.

Tabula II.

Fig. 1. **Alnus Yasha**: rami fructiferi in magnitudine naturali.

Fig. 2. Squama strobili $^5/_1$ aucta, antice visa.

Fig. 3–5. Nuculae $^5/_1$ auctae.

Tabula III.

Fig. 1. **Alnus pendula**: rami fructiferi in magnitudine naturali.

Fig. 2. Squama strobili $^5/_1$ aucta, antice visa.

Fig. 3–5. Nuculae $^5/_1$ auctae.

Tabula IV.

Fig. 1. **Alnus incana**, var. **emarginata**: rami fructiferi in magnitudine naturali.

Fig. 2. Squama strobili $^5/_1$ aucta, antice visa.

Fig. 3–5. Nuculae $^5/_1$ auctae.

M. Chiba del

Alnus Sieboldiana, Matsumura.

Matsumura Revis. Alni Specierum Japonicarum

Alnus Yasha, Matsumura.

Matsumura, Revisio Alni Specierum Japonicarum.

Alnus pendula, Matsumura.

Matsumura: Revisio Alni Specierum Japonicarum

Alnus incana, var. emarginata, Matsumura.

Matsumura, Revisio Alni specierum Japonicarum

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Notes on a New Fossil Mammal.

By

S. YOSHIWARA

AND

J. IWASAKI.

With 3 Plates.

In 1898 a fossil skull of a large mammal apparently of an unknown type came into possession of Mr. IWASAKI. Accordingly, in the following year, Mr. YOSHIWARA visited the locality where the skull was reported to have been discovered, in order, if possible, to ascertain its exact mode of occurrence. The place is called Togari, situated in Kanigōri, province of Mino, and the rock in which the fossil was found is a tufaceous sandstone belonging to the Neogene Tertiary, probably Miocene. In this sandstone Mr. YOSHIWARA found a specimen of a tooth belonging to the same mammal, a fact which confirms the discovery of the skull in the same rock. The strata lying considerably below the sandstone contain *Vicarya callosa* JENKINS † and many other marine shells, which are generally considered to be Miocene. Associated with the above bones there are

† K. Martin, Die Tertiärschichten auf Java. 1879–80, p. 62.

teeth of *Carcharias japonicus* SCHLEG., *Solen*, and impressions of some land plants (Pl. III. fig. 6 a). The occurrence of these plant-remains shows that the deposits, although marine, are of a shallow water origin.

About half a mile from the above locality, and in a stratum identical in age with that of the above mentioned sandstone, Mr. YOSHIWARA dug out a part of the lower jaw of a *Rhinoceros* with some teeth in the sockets. Bones of another species of *Rhinoceros* were also found by him in the Neogene tufaceous sandstone of Hazaki, about 6 miles from Togari. This was the first time that the remains of *Rhinoceros* had ever been discovered in Japan.

Detailed examination of the fossil skull mentioned seems to show many characters which are different from those of any other mammal hitherto described. A few peculiarly shaped bunodont molars and many tusk-like incisors, together with the long, narrow, flat and straight upper jaw, and a large, anteriorly placed, united nasal foramen are some of the significant characters which distinguish the fossil. The shape of the molars strongly reminds us of those in the *Mastodon*; but the peculiar arrangement of their cusps, the presence of many thickly enamelled incisors in both jaws, and the general outline of the skull, exclude the idea of the fossil belonging to that genus. Indeed in the shape of the skull our fossil resembles some of the Ungulates, amongst which order the groups possessing the bunodont teeth—a type of teeth generally considered to be of a primitive character—are represented by the Condylarthra, the primitive Equidæ (such as the Hyracotherinæ) among the Perissodactyla, and the Bunodontia among the Artiodactyla. But the small number of molars—viz. two premolars and one or two molars on each side of the jaw,—and six horizontal tusk-like incisors, together with the fact that the anterior end of the upper jaw protrudes somewhat over the

lower, are characters which distinguish our fossil from all the forms of hitherto known Ungulates. As an evidence that it is not a Sirenia, we may mention the differing position of the nasal foramen, the smooth surface of the upper jaw, the straight and not downwardly curved anterior ends of both jaws, the larger number of incisors and the peculiar form of the premolars and molars.

The discovery of this fossil is very important to the palæontology of Japan. But the lack of a sufficient literature concerning such fossils in our country compelled us to submit it to the examination of some recognized authority on vertebrate fossils abroad. So a brief description of the skull and teeth, accompanied by photographs, were sent to Professor OSBORN who was kind enough to inform us, that the skull belonged to the Proboscidea. According to this eminent vertebrate palæontologist, our form is a very primitive one in some respects, and a highly specialized one in other respects, belonging to the early types of *Mastodon*. The primitive characters of the fossil, he says, lie in the presence of successional incisors, while its highly specialized and aberrant characters lie in the peculiar form and arrangement of the mammilate cusps of the molars, and the narrow, compressed or connate roots supporting them.

The following is a detailed description of our new form.

SKULL.

The specimen is a very well preserved skull, whose hind portion, however, is broken away (Pl. I & II). It is small, compared with the skull of other Proboscidea, the length being considerably greater than the breadth. The whole length of the skull is 55^{cm} (1.8 ft.) ; from the anterior extremity of the upper jaw to the anterior

edge of the nasal foramen it measures 7^{cm}, and from the posterior edge of the same foramen to the anterior part of the orbit 20^{cm}. The nasal foramen is large, oval-shaped, 13^{cm} long and 6^{cm} wide, and placed quite in the anterior part of the skull (see Pl. I). The width of the skull running through the middle of the nasal foramen is only 13^{cm}, and the distance between the inner sides of the molars of the upper jaw is 11^{cm}. The height of the skull is more than 16^{cm} at the posterior end, but anteriorly from the point of the insertion of the molar teeth, it thins out quite rapidly. The molars are found immediately beneath the orbital foramen as shown in Pl. II. Towards the nasal foramen the jaw becomes more and more flattened, and is only 5^{cm} high at the posterior edge of the foramen, whence it thins out towards the anterior extremity. When viewed from above, the nasal foramen is completely surrounded by the premaxillæ, and the nasal bones do not extend to the foramen but lie beneath the premaxillæ. Maxillæ are well preserved, joined to other bones by distinct sutures. The upper surface of the upper jaw is almost smooth and its anterior portion shows no trace of a downward curvature.

The lower jaw is very low and also does not curve downward. Its ramus is 11^{cm} high and 4.5^{cm} wide at the part where the molars grow, but the height gradually diminishes towards the anterior part, finally thinning out at the extremity. The posterior end of the line of junction of the two rami is placed far back, being separated only about 5^{cm} in a direct distance from the root of the molar. The distance from a point between PM_2 and M to the anterior extremity of the ramus measures about 40^{cm} in the upper jaw, but only about 36^{cm} in the lower. This shows that the upper jaw protruded over the lower.

INCISORS.

The teeth are very characteristic in form. Incisors are all tusk-shaped, quite horizontally placed and not curved at the tip. There are found two pairs in the lower jaw and one pair in the upper. (See Pl. I). The upper incisors have not yet come into full growth, only the left tooth being slightly visible below the broken maxillae. The two pairs of incisors in the lower jaw, especially the inner pair or I_1. are prolonged beyond the anterior extremity of the jaw bone. Incisors are very long and probably 20^{cm} or more in length when measured from the extremity of the root to the summit of the crown. They are entirely covered by a thick coating of enamel, with the thick dentine and the pulp cavity inside. In the lower I_2, a transverse section at the distance of 7.8^{cm} from the summit has the diameter of 3.15^{cm}, where the enamel is 1.5^{mm} thick, the dentine 6^{mm} and the diameter of the pulp cavity 1.65^{cm} (fig. 1). Towards the summit, the enamel becomes thicker measuring 3^{mm} in thickness, while the dentine has the diameter of 1.4^{cm} with no pulp cavity at the distance of 3.2^{cm} from the summit (fig. 2). The upper jaw seems to have only one pair of incisors, for the transverse section of the skull at the distance of about 22^{cm} from the anterior extremity shows no trace of teeth (fig. 4).

PREMOLARS AND MOLARS.

Behind the incisors there is a wide gap in both jaws. The teeth collected by us are the right lower PM_1, the right upper PM_2, the right and left lower PM_2, the left lower M, and the right and left upper M. They all possess very peculiar forms never found in Proboscidea, or even in other Mammalia. The crown is an aggregation of long cylindrical column-like tubercles, which are generally arranged in two longitudinal rows, parallel to the longer axis of the crown, and in

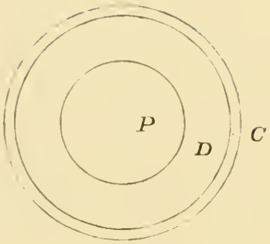

Fig. 1.

Section of $Lo I_2$ at the distance of 7.8cm from the summit (nat. size).

C Cement.
D Dentine.
P Pulp.

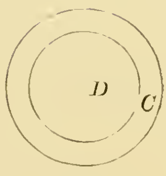

Fig. 2.

Section of $Lo I_2$ at the distance of 3.2cm from the summit (nat. size).

C Cement.
D Dentine.

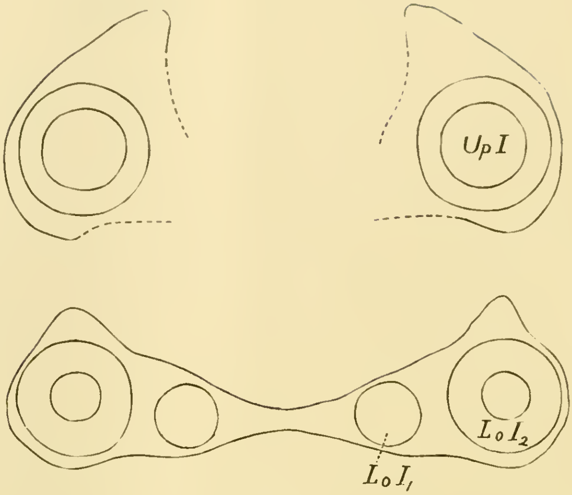

Fig. 3.

Diagrammatic transverse section of skull at the distance of 15cm from the anterior extremity of the upper jaw. ($\frac{1}{2}$ nat. size).

Up I Upper incisor. *Lo* I_1 First lower incisor.
Lo I_2 Second lower incisor.

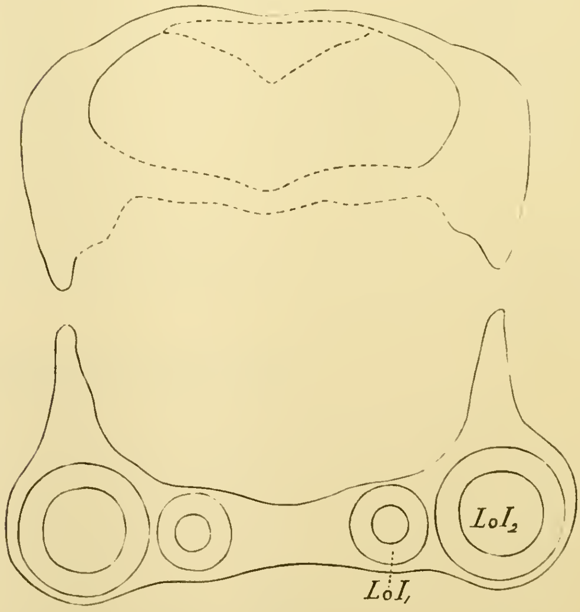

Fig. 4.

Diagrammatic transverse section of skull at the distance of 22cm from the anterior extremity of upper jaw. ($\frac{1}{2}$ nat. size).

Lo I_1 First lower incisor. *Lo* I_2 Second lower incisor.

three transverse rows at right angles to it. The enamel is extraordinarily thick, and the dentine which occupies the centre of the column appears as a round section on the masticating surface. The base of the teeth is narrow, compressed and 2-rooted in all cases. The pulp cavity is almost wanting in the crown, only extending as a small rounded canal in each tubercle for a very short distance. Although we could not examine any other premolars than the last premolar in the upper jaw, yet it is almost certain that there must have existed another premolar located anteriorly, judging from the well worn surface of the lower premolar corresponding to it.

First premolar : The premolars of the lower jaw are two in number. The crown in the first premolar (Pl. III. fig. 1 a & b) has a longer axis of 3.2^{cm}, a shorter axis of 2^{cm}, and a height of about 2.7^{cm}. It is composed of seven pillars, which are not so distinctly separated into two symmetrical halves as is seen in the succeeding teeth. These pillars are very close together so that there is no space left between them. So when seen from above, the pillars are not circular in section, but appear strongly compressed toward one another. The masticating surface is comparatively little worn, so that the dentine is not much exposed on it. The posterior side of the tooth presents neatly fitting faces to the second premolar, but on the anterior side we can not find any face which might have come in contact with another tooth.

Second premolar : The second premolar of the lower jaw (Pl. III. fig. 2 a & b, fig. 3 a & b) has a longer axis of 4.7^{cm} and a shorter axis of 3.2^{cm}, while the height of the crown is reduced to 2.5^{cm}, as the result of much friction. It is divisible into two longitudinal halves and three transverse parts. Each of these parts consists of a column-like tubercle with the thick outer enamel and the

centrally placed dentine. Only in the posterior outer one of these parts is there found by the side of a larger ordinary pillar another smaller one, which corresponds to the talon of other bunodont mammals. At the base of the middle of the anterior side, there is a little protuberance which however has been almost entirely worn away by rubbing with the first premolar.

The second premolar of the upper jaw (Pl. II. Pm, Pl. III fig. 4) is only seen on its right side. The crown is composed of four cylindrical pillars and a very small protuberance at the anterior outer edge. Thus the teeth of the upper jaw, when compared with those of the lower, show much fewer tubercles. This fact is probably not due to the loss of tubercles by mechanical action after the death of the animal, but seems to have been a natural state, for, on examining the corresponding PM_2 in the lower jaw, we find that the surface in contact with the former is deeply worn in, so that the surrounding portion projects a little over the other parts. This projecting portion is also worn by friction, which indicates the existence of PM_1 in the upper jaw.

Molars: Molars are very large and distinctly 2-rooted. The molar of the lower jaw (Pl. III. fig. 5 a & b) has a length of 6.4^{cm} and a breadth of 4^{cm}; and the height of the worn crown measures 3.9^{cm}. It closely resembles in form the lower PM_2 but is much more simple, being composed only of six regular pillars.

The molars of the upper jaw (Pl. II. M_1, Pl. III. fig. 4, fig. 6 a & b) are rather complex in form. The outline of the masticating surface takes the form of an isosceles triangle with the apex directed posteriorly. The pillars are arranged in two longitudinal and four transverse rows. The transverse row making the base of the triangle is formed of three pillars with a smaller one intercalated between the two innermost pillars of this and the next posterior row.

The central rows are composed of two anterior and two posterior pillars of which the anterior ones are the largest of all. At the apex of the triangle are two pillars, the larger being placed almost in the median longitudinal line and the smaller in contact with it at the inner posterior edge.

Near the posterior margin of the right orbital foramen, a trace of a molar is found enclosed in the bone (Pl. II. M_2). Judging from its position, as well as from the young state of the animal, it is probably to be considered as the second molar which was not yet functional as in the case of the upper incisor. As the posterior portion of the lower jaw, posterior to the position of the first (?) molar, is broken away, it is not certain whether the second (?) molar ever existed.

From the above statement it is to be concluded that the animal had probably two incisors, four (?) premolars and four molars in the upper jaw, and four premolars and two or four molars in the lower.

It is of interest to add here, that another tooth probably belonging to the same genus, if not to the same species, was brought by a Mr. S. Itō in 1897 from an entirely different locality. He is a resident of the village of Yunomachi near Matsue in the province of Izumo, and it was reported by him that the specimen had been picked up by another person in the vicinity of the village. It (Pl. III. fig. 7 a & b) has a crown which is quite similar in color and structure to the above described teeth. The crown is likewise split by a longitudinal furrow running down to its base. The small number of tubercles in the tooth seems to indicate that it is a lower molar, but the crown is very small in size when compared with the specimens already described, being only 4.3^{cm} in height, and 3.5^{cm} and

2.9^{cm} in the longer and shorter axes on the masticating surface. Moreover the pillars are not arranged in three transverse rows, and there is no sign of either its anterior or its posterior face having been in contact with another tooth. The outer surface of one of the two longitudinal halves containing three tubercles is convex, but that of the other half is almost flat. The wearing is rather slight and the dentine is exposed only in a small round section. The two-rooted character of the base is distinctly shown in the tooth examined. Comparing the form of the present tooth with that of the above described specimens, there is among these not one which quite agrees with it in the arrangement of the column-like tubercles. In the size of the crown the tooth somewhat approaches the second premolar of the other specimens, but there exists a great difference in the number of tubercles. Therefore it is not certain whether we have before us a premolar or a molar, a milk tooth or a permanent one.

PHYLOGENETIC VIEW OF THE PRESENT SPECIMENS.

Our specimens decidedly belong to a new genus. Among the Proboscidea there are at present two families, viz.. Dinotheridæ and Elephantidæ. The former contains only one genus called *Dinotherium*, which is found in the upper and middle Miocene (or even in the Pliocene?) of Europe and the East Indies. The animals which are commonly known as elephants are all included in the latter family which comprises three genera *Mastodon*, *Stegodon* and *Elephas*. The chief characters which distinguish those families from one another seem to me to be the following :

(1) In the Dinotheridæ a pair of incisors appear only in the lower jaw, and are directed vertically downwards in consequence of the abrupt downward flexure of the front part of the mandible, while in

the Elephantidæ they appear either only in the upper jaw as seen in *Elephas*, *Stegodon* and many species of *Mastodon*, or in both jaws as in some other species of *Mastodon*.

(2) In the Dinotheridæ the grinding surface of the molars is provided with very simple transverse ridges which are three in number in the first molar, and two in the other molars, and are entirely destitute of cement; while in the Elephantidæ the construction of the teeth is more complicated. Some species of *Mastodon*, in which the teeth show a very simple construction, have two or more transverse ridges with somewhat deeper valleys, and also show a tendency for each ridge to divide itself into a right and a left half, while most frequently these ridges are further subdivided into tubercle-like bosses. In *Elephas* the ridges become very numerous and are separated from one another by deep cleft-like valleys filled with thick cement, while in *Stegodon* the teeth present the transitional form between those of *Elephas* and *Mastodon*.

(3) In the Dinotheridæ all the teeth (two premolars and three molars) are simultaneously functional, while in the Elephantidæ there are no more than one or two in place and in use at all times.

Now examining the Japanese specimens, there are many characters which distinguish them from the two families above described. Indeed the distinction is quite as great as that existing between these two. The Japanese form has a great number of incisors, viz., one pair in the upper jaw and two pairs in the lower. Although the specimens seem to belong to a young form and the incisors are not yet perfectly developed, there is reason to believe that they will not develop so strongly as to form tusks which are seen in the above two families. In the fact that the premolars and molars are all simultaneously functional, they resemble *Dinotherium*, while their

peculiar form reminds us of the most primitive teeth of *Mastodon*. The great elongation of both jaws which are narrowed and quite flattened, the anterior position of the nasal foramen, and the much narrowed and compressed roots of the teeth are characters quite different from those of Proboscidea, if we except some very aberrant forms. In the Japanese form, the enamel is thick and covers the whole surface of the incisors. Such a case is never found in the hitherto described Proboscideans ; *Stegodons*, most *Elephas* and the Pliocene *Mastodons* having no trace of enamel. The only cases in which the presence of enamel has been ascertained are those of some Miocene species of *Mastodons*, and of some *Elephas*. But in the former the enamel covers only the lateral side of the tusks as a longitudinal band, and in the latter it covers only the apex of the teeth which, however, soon wears away. Thus the great number of thickly enamelled small incisors and the most primitive form of premolars and molars which are all simultaneously functional, are the characters which make the Japanese fossil approach to the primitive Ungulata, from which Proboscidea is supposed to have descended. Our form also resembles, in some respects, certain Sirenia, viz., in the structure and number of incisors, in the bunodont character of the molars, in the thinning out of both jaw bones anteriorly, and in the protrusion of the upper jaw over the lower, &c. It is true that Sirenia has a close relationship with the Ungulata; its most primitive form, *Prorastomus*, having a great number of incisors, a pair of canines, and a smooth, straight and slender upper jaw, all which characters decidedly show its descent from an Ungulata like *Phenacodus* or *Tapirus*. LYDEKKER is of opinion that *Halitherium veronense* ZIG. is a form which has descended from an artiodactyle Ungulata with short-crowned and solenodont molar teeth. ZITTEL also mentions that the molars of Sirenia resemble partly those of the

Tapirus and partly those of the primitive hog or Condylarthra. So it is quite natural that there should exist some coincidence in the characters of the three orders of Sirenia, Proboscidea and Ungulata, and that our new form which shows very primitive characters of Proboscidea should also resemble the two other orders above mentioned.

We here express our great indebtedness to Professor H. F. OSBORN for the valuable hints given to us in his very kind letters during our investigations. Thanks are also due to Professors YOKOYAMA and WATASÉ for the trouble they have taken in revising our manuscript.

Palæontological Laboratory,
Science College,
Tōkyō Imperial University.

December 1901.

PLATE I.

PLATE I.

Upper view of skull (reduced to one half of natural size).

Fr	Frontale.	Up I	Upper incisor.
Na	Nasale.	Lo I_1	First lower incisor.
Pmx	Premaxillæ.	Lo I_2	Second lower incisor.
Mx	Maxillæ.	Pm_1	Root of first lower premolar.
Md	Mandible.	Pm_2	Root of second lower premolar.
		M	Contacting position of lower molar.

Portion colored light purple showing sandstone matrix.

Ishizaki del.

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PLATE II.

PLATE II.

Profile view of skull (reduced to one half of natural size).

Pmx	Premaxillæ.	Lo I_1	First lower incisor.
Mx	Maxillæ.	Lo I_2	Second lower incisor.
Or	Orbital foramen.	Pm	Upper premolar.
Md	Mandible.	M_1 & M_2	Upper molars

Portion colored light purple showing sandstone matrix.

Ishizaki del.

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Yoshiwara and Iwasaki—On a New Fossil Mammal.

PLATE III.

PLATE III

Fig. 1 a & b. View of the masticating and outer surfaces of the first right lower premolar; anterior surface on the right side of plate.

Fig. 2 a & b. View of the masticating and outer surfaces of the second right lower premolar; anterior surface on the right side of plate.

Fig. 3 a & b. View of the masticating and outer surfaces of the second left lower premolar; anterior surfaces on the left side of plate.

Fig. 4. View of the masticating surface of the right upper premolar and the right upper molar; anterior surface on the right side of plate.

Fig. 5 a & b. View of the masticating and outer surfaces of the left lower molar; anterior surface on the left side of plate.

Fig. 6 a & b. View of the masticating and inner surfaces of the left upper molar; anterior surface on the left side of plate.

Fig. 7 a & b. View of the masticating and convex surfaces of the specimen from the province of Izumo.

All figures in natural size.

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Yoshiwara and Iwasaki— On a New Fossil Mammal.

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Studies in Atmospheric Electricity.

By

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With Plates I—IV.

GENERAL DESCRIPTION.

The facts to be discussed below have been obtained chiefly from the "Report on Observations in Terrestrial Magnetism and Atmospheric Electricity made at the Central Meteorological Observatory of Japan for the Year 1897," though some are from the original photographic records preserved in that observatory. The observatory, whose coordinates are $\phi = 35° \, 41' \, \mathrm{N.}$, $\lambda = 139° \, 45' \, \mathrm{E.}$, occupies a portion of the old castle of Yedo, and thus stands pretty well out of the direct effect of the dust and smoke of the city. The collector for atmospheric electricity is a water-dropper whose nozzle is 2 m. from the wall of the building and 1.7 m. above the ground. The photographic record is given by a Kelvin-Mascart's self-recording electrometer. The time refers to the central standard time, *i.e.* the mean time for the meridian 135° E. Other details with regard to the observation and reduction will be found in the first pages of the Report.

Every one looking at the photographs will be struck by the most irregular and capricious manner, in which the potential varies from instant to instant. (See PL. I.) This fact, together with the observations of Lord Kelvin and others that at two stations distant from each other by more than 100 m., no similarity in the variations could be detected, suggests to us that the principal causes of the phenomenon are located not very far from the earth, but perhaps within a few kilometres from, and possibly just near the surface.

On examining the figures given in the Report, we see at once that the cold seasons show a decided tendency to have higher potentials than the warm. While fully recognizing this tendency, we feel some hesitation in accepting these figures as representing the genuine values of the potential at all seasons. Probably defective insulation of the instrument in the warm and wet season has some part in the effect.

Undoubtedly the diurnal variation is much more faithfully represented. Here we see two maxima and two minima, somewhat resembling the variation of the atmospheric pressure, with which the phenomenon has probably a close connection. As to the time of

	Min.	Sunrise	Max. (Volt)	Min. (Volt)	Sunset	Max.
Jan.	3.45 a.	6.50 a.	7.45 a. (171)	2.30 p. (47)	4.50 p.	9.00 p.
Feb.	3.00 a.	6.29 a.	7.45 a. (143)	noon (22)	5.21 p.	10.00 p.
Mar.	4.15 a.	5.52 a.	6.45 a. (104)	3.00 p. (12)	5.47 p.	10.45 p.
April	2.00 a.	5.10 a.	6.15 a. (119)	3.00 p. (5)	6.13 p.	12.00 p.
May	—	4.39 a.	6.15 a. (74)	2.30 p. (4)	6.37 p.	—
June	3.00 a.	4.27 a.	6.00 a. (49)	1.00 p. (3)	6.55 p.	9.00 p.
July	2.00 a.	4.39 a.	6.00 a. (21)	2.15 p. (3)	6.53 p.	9.00 p.
Aug.	2.00 a.	5.01 a.	6.15 a. (14)	2.45 p. (2)	6.27 p.	8.45 p.
Sept.	3.00 a.	5.25 a.	6.45 a. (19)	2.00 p. (2)	5.46 p.	12.00 p.
Oct.	2.00 a.	5.50 a.	7.00 a. (103)	noon (25)	5.05 p.	9.00 p.
Nov.	3.15 a.	6.18 a.	7.30 a. (108)	2.15 p. (38)	4.35 p.	10.00 p.
Dec.	3.45 a.	6.44 a.	8.00 a. (188)	2.45 p. (42)	4.30 p.	10.00 p.

occurrence of the extreme values in each monthly mean, we have the accompanying table.

Thus we see that the morning maximum occurs a little more than one hour after sunrise, throughout all the seasons. The fact that this maximum occurs much more regularly than the other extreme values, is not confined to the monthly means, but also exhibits itself in daily values. For, it generally deviates only an hour or two from one day to another, while the evening maximum, for instance, may occur at 7 p.m., or not be reached even at midnight. This fact is at least one of the causes which make the morning maximum so conspicuous in the diurnal variation curve in each month.

THEORIES.

Before proceeding further to examine the relations of the potential to other meteorological phenomena, it will be well here to recapitulate briefly some of the theories of atmospheric electricity, and to state the author's view in accordance with which be wishes to discuss those relations.

Perhaps the oldest of the theories still held is that of Erman (1803) and Peltier (1836), which supposes the earth to have an inherent negative charge. Among the modern supporters of this theory we find Exner, who, while ascribing the primary cause of atmospheric electricity to the earth's inherent charge, strives to explain its variations as being due to the action of the aqueous vapour, which in evaporating from the earth's surface, carries more or less negative charge with it,[1] the latter supposition being founded on

1) Exner, Sitzungsberichte d. Wiener Akad. d. W. **93.** p. 222. 1886; **95.** p. 419. 1887; **97.** p. 277. 1888.

an experiment of Mascart's, who observed (1878) that the evaporation took place more rapidly from an electrified liquid than from a neutral one.

Edlund's theory[1] of unipolar induction considers the earth as a rotating conducting sheath, within which a magnet is situated. The induction, as he calculates, causes positive electricity to accumulate in the upper atmosphere, which is the origin of atmospheric electricity.

Sohncke[2] ascribed the cause of atmospheric electricity to the friction of ice on water particles, whereby, as was first shown by Faraday[3] and afterwards ascertained by Sohncke,[4] ice becomes positively and water negatively electrified. Thus the layer of air lying above the isothermal of 0° and carrying ice spicules, becomes pesitively electrified by friction with the layer lying below the isothermal and containing water particles, and the negative electricity of the latter partly passes down to the earth through precipitation.

The photoelectric theory, which was first proposed by Arrhenius,[5] and then somewhat modified and fully developed by Elster and Geitel,[6] considers that the negative electricity of the earth's surface is dissipated in the atmosphere by the action of the ultraviolet light from the sun. Some relations are traced between the seasonal and diurnal variations and the intensity of the solar radiation.

The so-called ion-theory of atmospheric electricity was first suggested by J. J. Thomson,[7] during his investigation on the charge

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1) Edlund, Actes de l'Academie des Sciences de Suéde, **XVI**. 1878.

2) Sohncke, Der Ursprung der Gewitter-elektricität und der gewöhnlichen Elektricität der Atmosphäre, Jena. 1885.

3) Faraday, Experimental Researches, **II**. p. 106.

4) Sohncke, Wied. Ann. **28**. p. 550. 1886.

5) Arrhenius, Meteorologische Zeitschrift, **5**. p. 297. 1888.

6) Elster und Geitel, Sitzungsberichte d. Wiener Akad. **101**. p. 703, 1892.

7) J. J. Thomson, Phil. Mag. **XLVI**. p. 533. 1898.

of electricity carried by the ions produced by Röntgen rays, in the following terms. "If the negative ions, say, were to differ in their power of condensing water around them from the positive, then we might get a cloud formed round one set of ions and not round the other. The ions in the cloud would fall under gravity, and thus we might have separation of positive and negative ions, and the production of an electric field, the work required for the production of the field being done by gravity." C. T. R. Wilson[1] actually found that it requires a greater expansion to produce a cloud on positive ions than on negative ones, and he considers that if ions ever act as condensation nuclei in the atmosphere, it must be mainly or solely the negative ones which do so, and thus a preponderance of negative electricity will be carried down by precipitation to the earth's surface. Elster and Geitel[2] observed that an isolated charged body gradually loses its electricity when exposed to the atmosphere, the negative electricity being, generally speaking, the more quickly dissipated. They investigated the phenomenon under various circumstances, and came to the conclusion that solar radiation gives a kind of conductivity to the air, by generating in it some minute nuclei capable of carrying electric charges, which they called *ions*. Of these the negative ions move more quickly than the positive, and soon reach conductors such as the earth's surface, and give up their negative charge, while the positive ions remain and accumulate in the atmosphere. Thus the usual electric condition of the atmosphere is set up and maintained. Ebert[3] repeated the experiments in balloons and found that the rate of dissipation is greater in the higher altitudes

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1) C.T.R. Wilson, Phil. Trans. 1899, or Nature **LXII**. p. 149. 1900.

2) Elster u. Geitel, Terr. Mag. **IV**. 1899, or Ann. d. Phys. 2. p. 425. 1900.

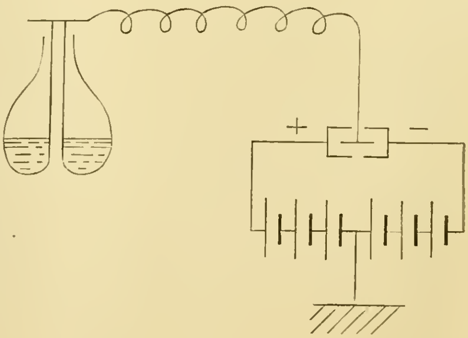
3) Ebert, Sitzungsberichte d. mathem.-phys. Classe d. kgl. bayer. Akad. d. W. **XXX**. p. 511, 1900; **XXXI**. p. 35. 1901.

and also that the rate gradually tends to become independent of the sign of the charge.

Now all of the above mentioned theories are based on experiments, and the actions or processes contained in them may actually take place in the atmosphere. The only question is that of the competence. For my part, I feel convinced that friction is by far the most effective cause of electrification. It is my main object here to see how far we can explain the manifold phenomena in atmospheric electricity by the friction theory alone.

EXPERIMENTS.

First of all, in order to assure myself, how different objects become electrified, I made the following experiments. I took a Kelvin-Mascart's electrometer, whose quadrants were charged by a water battery, the middle point of which was connected with the earth. To the needle was connected one end of a fine wire, the other end of which was put on a Mascart's insulator. The sensibility of the needle was about 0.17 volt per division of the scale.



Experiment I.—The friction of sand particles with leaves, twigs, wood, etc. These objects were placed one by one upon the Mascart's insulator, and from a metallic funnel suspended by silk thread, a stream of fine sand was poured down against them, so as to electrify them by friction. In each case, the electrometer showed a positive electrification. These objects were then disconnected from the wire, and held by a separate stand over the insulator. A stream of sand

passing down against them, was received by a plate on the insulator. The electrometer showed negative electrifications. From these experiments we may conclude that the above named objects become positively, and sand negatively electrified by their mutual friction.

Experiment II.—The friction of water particles with leaves, twigs, wood, etc. These objects were placed upon the insulator, and to them was directed a jet of steam from the finely drawn out end of a horizontal glass tube 1.5 m. long, whose other end was bent down into a flask of boiling water. The electrometer showed slight negative electrifications of these objects, except in one case, namely dry ice, which showed itself positively electrified. Though this group of experiments gave results with less degree of certainty than the rest, I contented myself with them; for exactly the same results had been already obtained by many investigators. For instance, Faraday[1] proved in his famous experiments conducted for the explanation of Armstrong's hydroelectric machine, that water becomes positively electrified by friction with many substances, for instance, ivory, quartz, glass, etc.; but becomes negatively electrified by friction with dry ice. Elster,[2] in investigating the electromotive force excited in a stream of water, showed that the electrification took place solely where the water was in contact with solids such as mica, agate, caoutchouc, wax, glass, porcelain, etc., and where the water mass experienced friction, and that the electrification was such that water acquired positive electricity with regard to these substances. Again Sohncke[3] proved that ice became positively electrified by friction with water, and also that ice was positive against all the substances he tried, e.g. steel, brass, glass, dust in the air, etc.

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1) Faraday, Experimental Researches, II. p. 106.

2) Elster, Wied. Ann. 6. p. 553. 1879.

3) Sohncke, Wied. Ann. 28. p. 550. 1886.

Experiment III.—The contact of hot and cold air. A piece of lighted candle was placed on the insulator, so as to serve as a collector. When a gas flame was brought near it, the electrometer showed a negative electrification, amounting to 10 divisions or more. When, however, the gas was opened unlighted, no electrification was observed. Not only the gas flame, but the flames of lamp and candle, and even a heated piece of iron, produced the same effect of negative electrification. The same effect, though in much less degree, was obtained when a current of warmed air was sent against the collector. The opposite effect, *i.e.* positive electrification was obtained, when a current of air cooled by a freezing mixture, was blown against the collector. These experiments show that when two masses of air at different temperatures are in contact with each other, the hotter one becomes negatively and the cooler one positively electrified. In order to verify this rather important conclusion, I caused two adjoining rooms to have temperatures of 10° and 20° respectively, and placed the candle flame collector on the insulator just near the connecting door. On slightly opening the door, the flame was at once blown towards the warmer room, and the electrometer showed an increase of potential, which was precisely the result expected.

Now as is well known, such experiments on statical electricity are usually associated with a greater or less degree of capriciousness and uncertainty, and, I confess, my case was no exception. It must be added, however, that the experiments were repeated over and over again, and that nearly all the eye observations of the electrometer were carried out by my two assistants, who had not been informed of what I was expecting to obtain.

EXPLANATIONS OF SEVERAL PHENOMENA.

In explanation of the general distribution of atmospheric elec-

tricity, I agree with Sohncke. Only I consider in addition, that the contact of warm and cold air, the intensity of wind, and the amount of dust are circumstances having no in-considerable bearing upon the phenomena, especially upon the seasonal and diurnal variations. Against Sohncke's theory, it has been objected that in winter it is not seldom that the isothermal of 0° does not lie at all within the atmosphere, and the explanation of the high potential at a low temperature much below the freezing point, seems to present an insurmountable obstacle to the acceptance of this theory. Again that, if an inversion of temperature occurs, so that the freezing point is reached at a cetain height from the surface, the potential gradient will become negative, a result utterly contrary to experience.[1)]

To the first objection we may reply that probably the isothermal of 0° always exists in the atmosphere, when the weather is calm and the sky is clear. Some instances of temperature measurements in balloons, which point to the above conclusion, may be mentioned.

On Nov. 10, 1900, after a few days' continuance of calm and anticyclonic weather, and under a perfectly clear sky, Ebert[2)] in Münich measured the following temperatures: 4°.2 at 1975 m. (8.56a.–9.11a.); 2°.7 at 2160 m.; 1°.7 at 2275 m.; 0°.5 at 2420 m.; –3°.8 at 2890 m.; –4°.7 at 2965 m. (10.38a.–10.53a.). On Jan. 17, 1901, under similar conditions, the same observer[3)] measured: –15°.2 at the surface (524 m.?); 1°.2 at 842 m.; (9.18a.); 1°.6 at 995 m.; 3°.0 at 1275 m.; 4°.4 at 1470 m. (10.02a.–10. 17a.); 4°.5 at 1550 m.; 4°.3 at 1650 m.; 3°.3 at 1930 m.; 2°.1 at 2285 m.; 1°.7 at 2375 m.; 1°.7 at 2560 m.; 0°.3 at 2880 m.; –1°.0 at 2930 m. (0.11p.–0.17p.);

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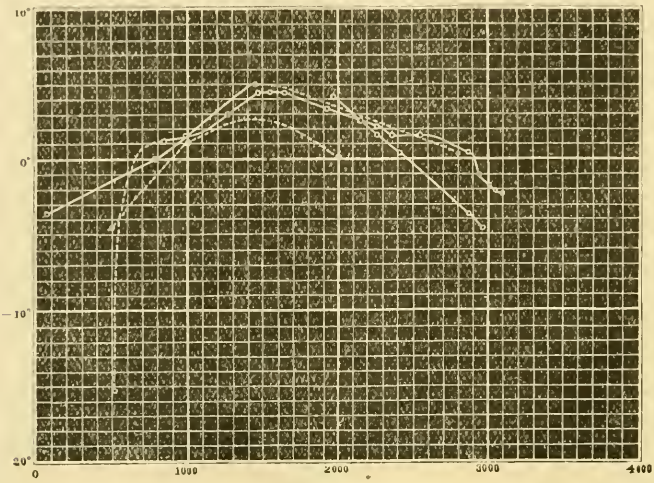
1) Elster u. Geitel, Zusammenstellung d. Ergebnisse neuerer Arbeiten ü. atmosphärische Elektricität. p. 11. 1897.

2) Ebert, Sitzungsberichte d. mathem.-phys. Classe d. kgl. bayer. Akad. d. W. **XXX**. p. 511. 1900.

3) Ibid. **XXXI**. p. 35. 1901.

$-1°.9$ at 3005 m.; $-2°.2$ at 3105 m.; $-2°.1$ at 3060 m. Again on the occasion of the international balloon ascents on Jan. 10, 1901,[1] a balloon from Vienna recorded the following temperatures: $-4°.6$ at



500 m.; 1°.2 at 1000 m.; 0°.2 at 2000 m. Another from Berlin recorded: $-3°.6$ at the starting; 0°.0 at 790 m.; 5°.0 at 1460 m.; 0°.2 at 2825 m.

Of course these will differ somewhat from the minimum temperatures of the day at the respective altitudes. But the difference, I believe, will be at most only a degree or two; for according to Hergesell,[2] the diurnal variations of the temperature at higher altitudes are very small, amounting, for instance, to 3° or 4° at 800 m., when the sky is clear, and much less when it is overcast. Also the days on which the above mentioned ascensions were made may be regarded as typical winter days with high pressure and severe frost on the ground, so that we may believe that the atmospheric conditions then observed are normal, and not exceptional. The meteorological

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1) Nature **LXIII.** p. 353. 1901.
2) Hergesell, Petermann's Geographische Mitteilungen Pt. **V.** 1900.

observations on Mount Tsukuba during January and February, 1893,[1] point to similar results. There the inversion of temperature was observed mainly during the night time when the sky was clear, namely, when the temperature at the lower regions was falling very low. Considering all these circumstances, I believe that it is not too much to say that under normal conditions a certain layer of air, say between 800 m. and 2000 m. or 3000 m., has temperature above 0°, even if the temperature near the surface be several degrees below 0°.

The second objection has no significance. For, if the general distribution of atmospheric electricity be already determined by the isothermal of 0° and other circumstances, and if then the earth's surface and layer of air near it be gradually cooled by radiation, so that the temperature sinks below 0° and there is formed a *second* isothermal of 0°, there can be no other result than the augmentation of the potential of the air near the ground.

EFFECT OF WIND.

Strong wind is generally accompanied by a low potential. Especially when the wind is strong enough as to raise dust in the atmosphere, the potential becomes negative even under a perfectly clear sky. (See Fig. 2.) It is worthy of notice that the potential remains positive, however violent the wind may be, provided the ground be wet with the previous precipitation and in consequence the dust does not rise in the atmosphere.

We may explain the phenomena by considering that the friction of dust particles on terrestrial objects gives a negative charge to the former and a positive to the latter, as Experiment I shows.

The following instances are picked out of the Report.

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1) Annual Report of the Central Meteorological Observatory of Japan for the Year 1893. Pt. II, p. 62.

Jan.	2.	N.	strong wind,	potential neg. 10a.–11a.
Jan.	16.	N.	strong wind,	potential low but pos. (*snow on 14th rain on 15th.*)
Feb.	2.		gale at M. N.,	potential low but pos. (*rain on 1st, 2nd.*)
Feb.	7.	W.	strong wind,	potential neg. 11a.–3p.
Feb.	11.	N.W.	gale,	potential neg. 10a.–4p.
Mar.	5.	N.	gale 3p.	potential pos. (*rain on 4th, 5th.*)
Mar.	6.	N.	gale –5a.	potential pos. and nearly constant.
Mar.	10.		gale,	potential pos. (*rain on 9th, 10th.*)
Mar.	11.		gale,	potential pos.
Mar.	13.		gale,	potential neg. 9a.–3p.
Mar.	24.		gale,	potential neg. 9a.–5p.
Mar.	31.		gale,	potential pos. –4 at 4p. (*rain on 30th.*)
April	7.	N.	gale,	potential neg. 2p–5p. (*rain on 6th.*)
April	10.		gale,	potential pos. but low towards afternoon. (*heavy rain on 9th.*)
April	11.	N.	strong wind,	potential neg. 1p.–5p.
April	22.		strong wind,	potential neg. 2p.–4p.
April	31.	S.	strong wind,	potential neg. 0p.–5p.
May	2.	S.	strong wind,	potential neg. 9a.–3p.
May	7.	S.	gale,	potential neg. 0p.–
May	15.	S.	strong wind,	potential neg. 8a.–5p.
May	22.	N.W.	gale,	potential neg. 0a.–5p.
May	28.	S.	strong wind,	potential neg. 10a.–5p.
May	29.	S.	strong wind,	potential neg. 11a.–2p.
June	2.		strong wind,	potential neg. 11a.–3p.
June	21.	S.	strong wind,	potential neg. 0p.–6p.
Oct.	30.	N.W.	gale from eve.,	potential neg. 8p.–
Oct.	31.	N.W.	gale,	potential neg. 0a.–4a., 9a.–1p.

Nov. 18. N. gale,	potential positive, but low towards afternoon. (*rain on 17th.*)
Nov. 25. N. gale,	potential low but pos. (*rain on 24th.*)
Dec. 27. N.W. gale,	potential neg. 10a.–4p.
Dec. 29. N. gale,	potential neg. 3p.–4p.

EFFECT OF FOG AND HAZE.

Mornings with fog or haze are generally characterized by a high potential with energetic fluctuations. (See Fig. 3.) Sometimes there are no sensible effect, and this we find mostly in cases when the ground is wet through previous precipitation. (See Fig. 4. and 5.) We may think that when the ground is dry, the particles of water become electrified positively with respect to the earth, while if the ground be wet, no electrification is produced.

A few instances are adduced.

Mornings with fog :—

Jan. 8. potential very high ;	April 6. potential high ;
June 18. potential high ;	June 29. potential high ;
July 25. potential high ;	July 26. potential very high ;
July 27. potential very high ;	Oct. 4. potential normal ;
Oct. 30. potential very high ;	Nov. 20. potential low (*rain on 19th*) ;
Dec. 3. potential high ;	Dec. 9. potential high ;
Dec. 10. potential high.	

Mornings with haze :—

Jan. 23. potential very high ;	Feb. 5. potential very high ;
Feb. 12. potential very high ;	Feb. 13. potential very high ;
April 8. potential high ;	April 23. potential very high ;
Dec. 10. potential high.	

EXCESSIVELY HIGH POTENTIAL.

If we pick out the days on which the potential was excessively high, we see that they are almost always days on which the temperature was excessively low. This result is not difficult to explain, for, as we have seen, the cold air will be positively electrified by contact with the warm air.

Here are a few instances.

Jan.	3.	0a.–12p.	clear	temp. low.
Jan.	8.	0a.–8p.	cloudy	temp. low.
Jan.	10.	4a.–12p.	fair	temp. low.
Jan.	26.	7p.–27. 11a.	cloudy	temp. low.
Jan.	28.	7p.–29. 6a.	cloudy	temp. low.
Feb.	5.	6a.–6. 9a.	clear	temp. low.
Feb.	8.	0a.–12p.	fair	temp. low.
Feb.	9.	0a.–11a, 8p.–11p.	fair	temp. low.
Feb.	13.	0a.–10a.	clear	temp. very low.
Mar.	6.	0p.–	clear	temp. low.
Mar.	14.	6a.–12p.	fair	temp. low.
Mar.	24.	5a.–12p.	clear	temp. low.
Mar.	25.	0a.–6p.	fair	temp. normal.
Mar.	29.	0a.–12p.	fair	temp. low.
Apr.	1.	0a.–1p.	cloudy	temp. normal.
Apr.	8.	0a.–9a.	clear	temp. low.
Apr.	23.	0a.–8a.	clear	temp. low.
May.	23.	0a.–1p.	cloudy	temp. low.
May.	26.	0a.–12p.	clear	temp. low. except 7a.–4p.
Oct.	15.	4a.–12p.	cloudy	temp. normal.
Oct.	20.	0a.–12p.	clear	temp. low.
Oct.	30.	0a.–3p.	fair	temp. normal, dense fog.

Nov.	2.	0a.–12p.	clear	temp. low.
Nov.	3.	0a.–12p.	clear	temp. normal.
Nov.	14.	0a.–12p.	clear	temp. low.
Nov.	30.	0a.–11a.	fair	temp. low.
Dec.	2.	5a.–12p.	fair	temp. low.
Dec.	18.	0a.–10a.	clear	temp. low.
Dec.	19.	0a.–12p.	fair	temp. low.
Dec.	30.	5a.–11a.	clear	temp. low.

EFFECT OF RAIN.

When the rain is moderate and the drops fine, the potential keeps very low positive values with only slight variations. When a down-pour takes place with sufficient violence, the potential becomes at once negative, and exhibits very irregular and energetic variations. As soon as the violence of the rain diminishes, the potential regains its positive value. (See Fig. 6.) These phenomena can all be explained in accordance with Lenard's investigation on the electricity of waterfalls.[1] Lenard proved by a series of the most conclusive experiments, that when a stream of pure water falls upon a metallic or other conductors previously moistened, the water droplets splashing in all directions become positively, and the air near them negatively electrified. There is no difficulty in applying this result to explain the negative potential in the case of a steady down-pour of rain. The summer rain gives sometimes a positive as well as a negative potential with violent variations. This is no doubt due to the proper charge of the rain drops, whose formation is probably something different from that in the case of the usual cyclonic precipitation. Usually a peal or two of thunder will be heard on such an occasion.

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1) Lenard, Wied. Ann. 46. 1892.

EFFECT OF SNOW.

In the case of a snowfall, the variation is much more regular, though no less energetic, than in the case of rain. The potential now increases in the positive direction, then decreases to zero and to extreme negative values, and then back again, etc. (See Fig. 7.) Whence may come such a quasiperiodic nature? As a matter of fact, the snowfall is attended with a greater or less periodicity; thus during one interval, there will be a heavy fall of fine snow; during next time the violence decreases and there will fall only scattered flakes. May not this fact have some connection with the above described manner of variation? On Feb. 25, 1901, there was a steady snowfall in the afternoon, and at 2 p.m., I measured the potential of the air outside the laboratory, and found it to be positive. At 4 p.m. the fall began to be scanty, and at 4.20 p.m. the potential was again measured, and was found to have a very great negative value. Since this was the only occasion I experimented on, it is unsafe to draw any conclusion from it, and I hope to make similar observations on the next available occasion.

ABNORMAL INDICATIONS.

There were two remarkable instances (see PL. IV) in which the potential showed abnormally great variations in both directions, positive and negative, while there was no precipitation, no thunder and no lightning. On May 26, a little before 4 p.m. the potential began to decrease suddenly, reaching extreme negative values at and near 4 p.m. Then it began to rise and crossed the zero-line at 4.20 p.m. and then as suddenly increased to reach its extreme positive value a little before 5 p.m. It then began to decrease, became negative again at and near 5.30 p.m., and then increased, and recovered its usual course at 6 p.m.

Now the temperature at those hours was: 22°.7 at 3 p.m.; 21°.9 at 4 p.m.; 18°.7 at 5 p.m.; 17°.7 at 6 p.m. The thermograph preserved in the Central Meteorological Observatory shows a sudden decrease of temperature from 4.00 p.m. to 4.30 p.m. The wind was NNW 4.6 at 4 p.m. and E 6.7 at 5 p.m. Thus we see that at about 4 p.m. a cold current of air suddenly came from the east. The negative potential at first observed was then the effect of the negative electrification of the previously existing warmer air, and the positive potential afterwards observed, of the positive electrification of the coming colder air on mixing with the former.

Again on Dec. 26, the potential began to get very high from 1 p.m. and was quite out of the paper at 1.30 p.m. It began to decrease and crossed the zero line at about 2 p.m., and became negative, and then gradually returned, till at 3 p.m. it had recovered its usual course, though much lower than it had kept before.

The temperature was 5°.0 at noon; 5°.3 at 1 p.m.; 11°.7 at 2 p.m.; 11°.9 at 3 p.m. The thermograph shows a sudden increase of temperature from about 1.45 p.m. to 2.00 p.m. The wind was NNW 2.0 at 1 p.m.; WNW 3.0 at 2 p.m.; SW 7.4 at 3 p.m. Thus we see that at about 1.45 p.m. a warm current of air came from SW. The positive indications at first observed were no doubt the consequence of the positive electrification of the colder air previously existing, and the negative indications afterwards observed, of the negative electrification of the newly arrived warmer air on mixing with the former.

CONCLUSIONS

A summary of the principal conclusions obtained from the above considerations is added here.

1. The negative potential observed during strong wind is entirely due to the negative electrification of the dust raised and carried in the atmosphere, by friction with terrestrial objects.

2. Similarly the high potential observed during fog or haze is due to the positive electrification of the water particles composing it.

3. When a mass of cold air comes in contact with a mass of warm air, the former becomes positively electrified with respect to the latter. This fact is probably one of the causes which determine the normal distribution of the electric field in the atmosphere. Also it may account for the fact that an abnormally high potential is generally accompanied by an abnormally low temperature.

4. The invariably high potentials at or near sunrise are probably due to the fact that the air lying near the surface has then a temperature lower than that of the air above it, and becomes, in consequence, positively electrified.

5. When two masses of air at different temperatures happen to be mixed suddenly, the elecric field is violently disturbed. The disturbances are, however, just such as are in accord with the fact stated in 3.

In conclusion, I wish to express my great indebtedness to Dr. K. Nakamura, director of the Central Meteorological Observatory, by whose kind permission, I have been able to examine several original records preserved in that observatory. The copies of photographs are also reproduced here through the courtesy of that gentleman. My best thanks are due to Professor Tanakadate and to Professor Nagaoka of the Tokyo University, who were kind enough to give me valuable suggestions, and to favour me with access to the literature of the subject.

Physical Laboratory, First High School.

Tokyo.

November, 1901.

PLATE I.

Fig. 1 represents a normal type of the potential. The weather was clear, with light to moderate winds.

Fig. 2 represents a case of the potential disturbed by a gale. On Apr. 11, 1901, NNW gale prevailed with the following intensities: 13.2 at 11 a. m., 12.6 at noon, 12.6 at 1 p. m., 11.7 at 2 p. m., 13.0 at 3 p. m., 9.9 at 4 p. m., 11.7 at 5 p. m., 7.6 at 6 p. m., 6.7 at 7 p. m., etc.

Fig. 1.

Feb. 12–13, 1900.

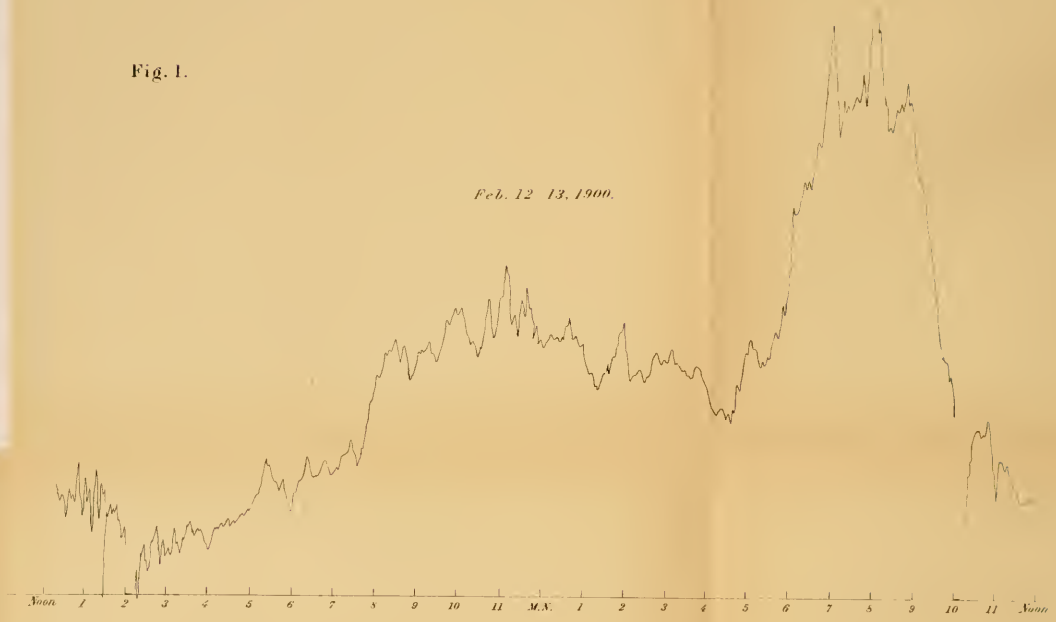


Fig. 2.

Apr. 11–12, 1901.

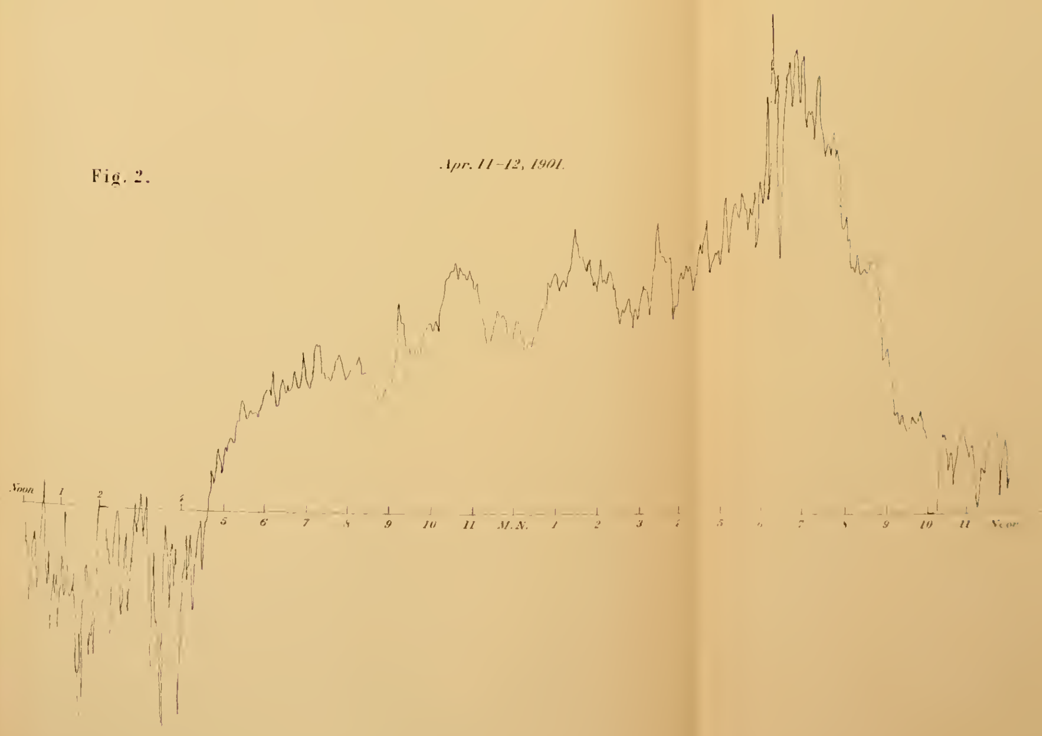


PLATE II.

Fig. 3 represents a very high potential on the occasion of a haze. The weather was exceedingly calm with perfectly cloudless sky. There was a thick haze from 8 a. m. to 11 a. m. on the 18th.

Fig. 4 represents a case of the potential undisturbed by a haze. On Oct. 14, 1900, there was a light rain in the afternoon, which ceased at 2.55 p. m. On the morning of the 15th, the weather was clear and calm, and the surface was very wet. There was a thick haze from 7 a. m.

Fig. 5 represents a case of the potential undisturbed by a fog. On Jan. 21, 1901, there was rain in the morning, which became light from 2.10 p. m. and ceased at 3.40 p. m. There were also some showers in the night. On the morning of the 22nd there was a fog.

Fig. 3.

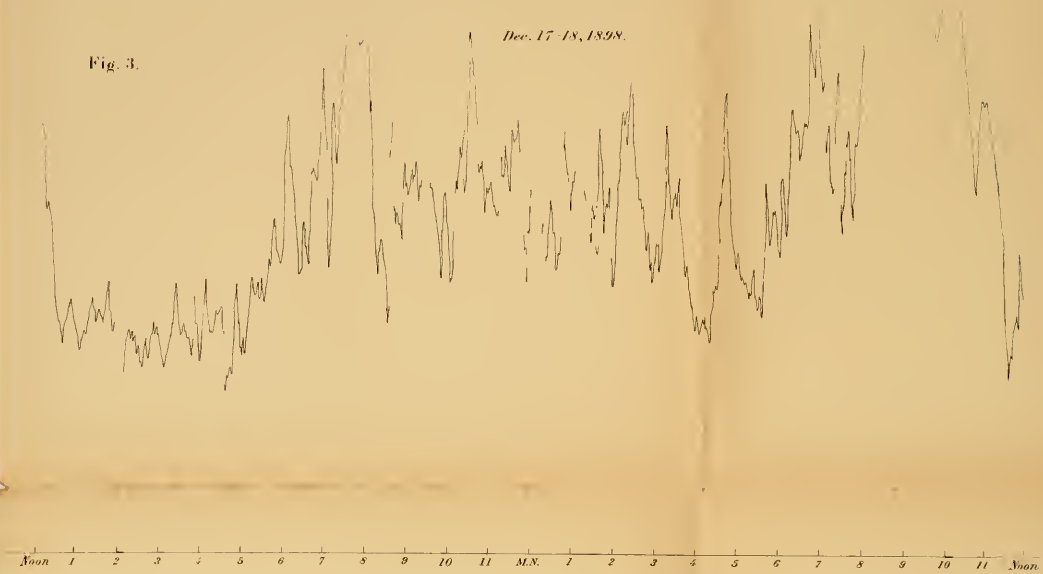


Fig. 4.

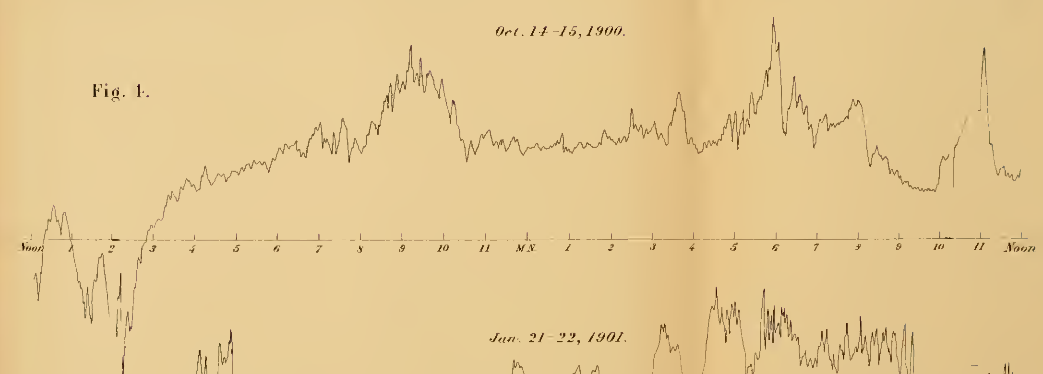


Fig. 5.

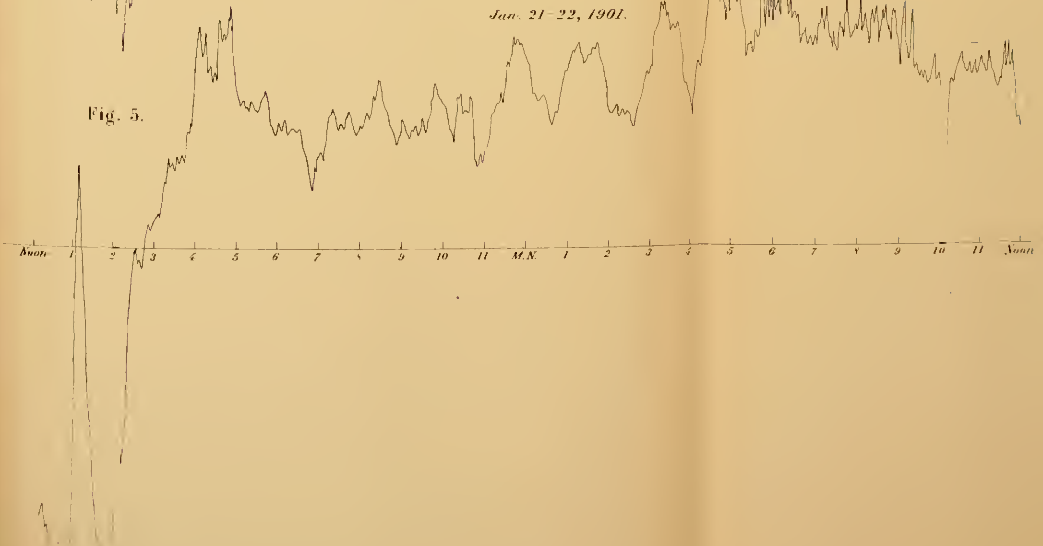
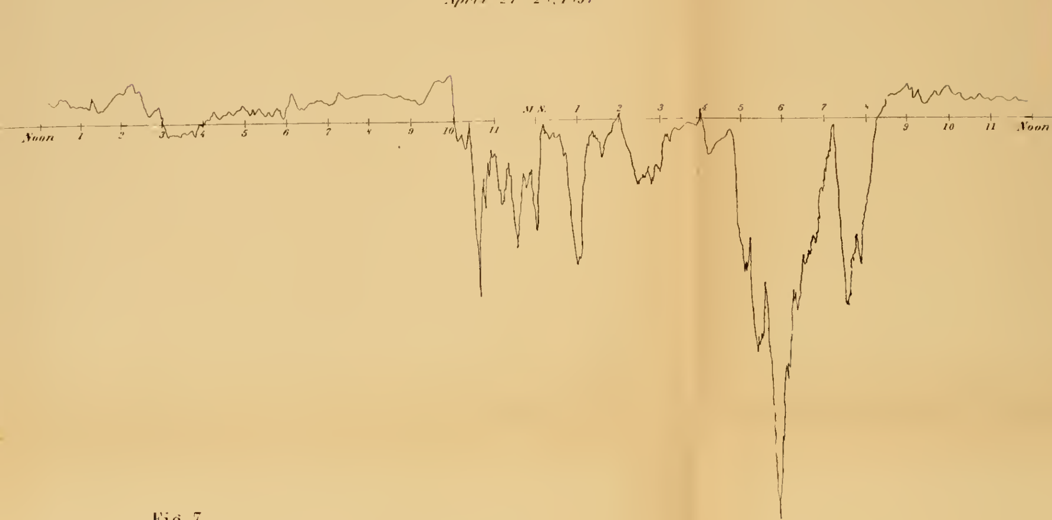


PLATE III.

Fig. 6 represents a case of the potential disturbed by rain. On the night of April 27, 1897, rain began to fall from 9.50 p. m. and continued to the morning of the 28th. There was a heavy fall between 5.10 a. m. and 6 a. m., on the 28th. It ceased completely at 9. 10 a. m.

Fig. 7 is a case of snowfall. On Jan. 21, 1900, snow began to fall at 6.15 a. m., continuing all the day, until at 6.30 p. m., the fall began to decrease and was accompanied by rain. The precipitation ceased completely at 9.55 p. m.

Fig. 6.


April 27–28, 1897
Noon
1
2
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6
7
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9
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11
M.N.
1
2
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6
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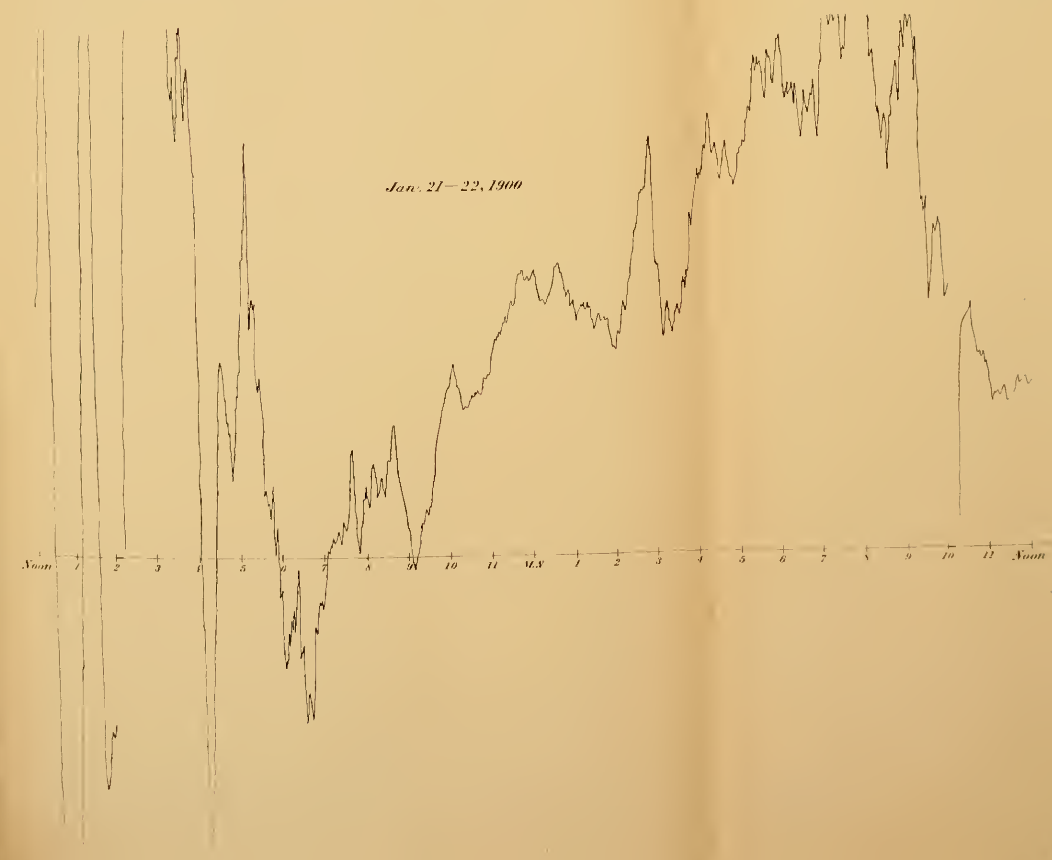
9
10
11
Noon

Fig. 7.


Jan. 21—22, 1900
Noon
1
2
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11
M.N.
1
2
3
4
5
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7
8
9
10
11
Noon

PLATE IV.

This represents two cases of abnormal variations. The constant determinations are represented in both cases, each corresponding to 100 volts. The dotted lines represent the variation of the temperature.

Fig. 8. *May 26, 1897.*

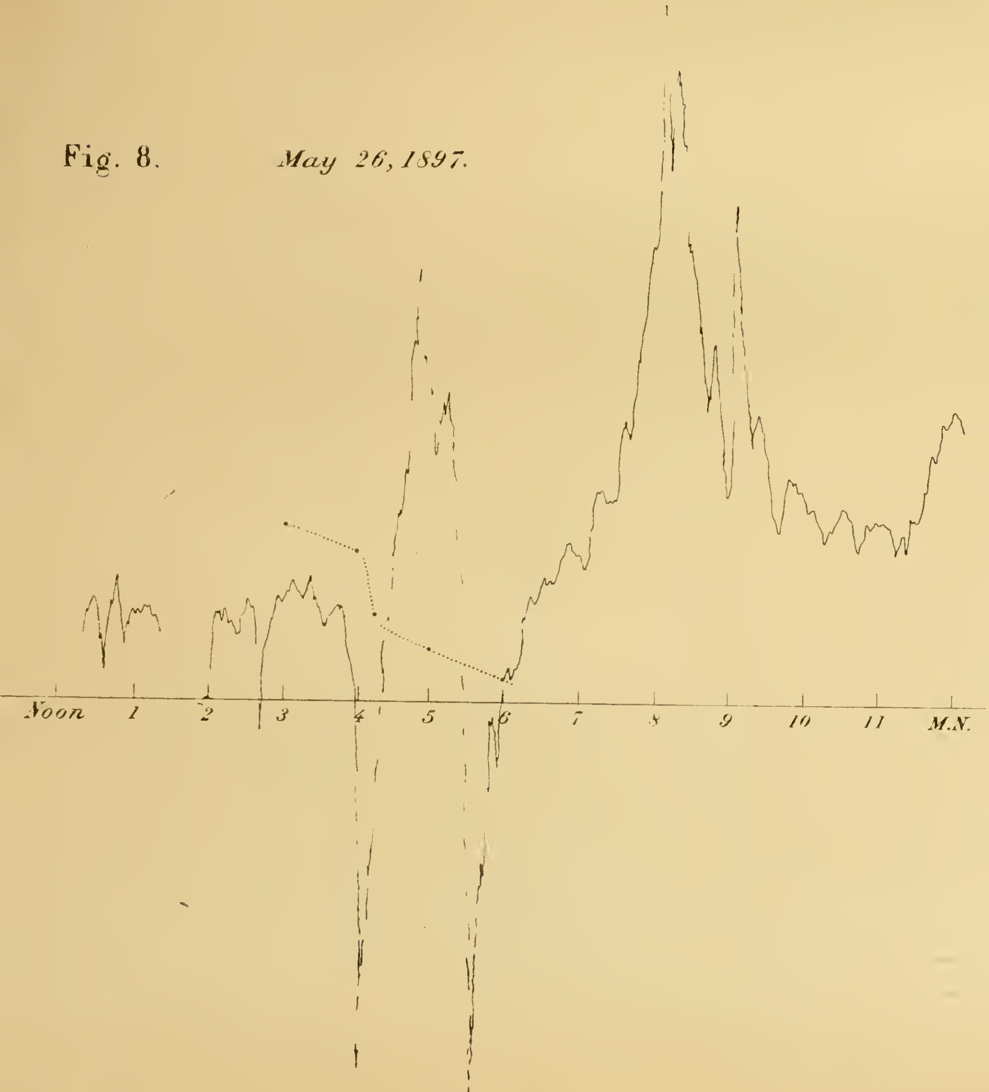
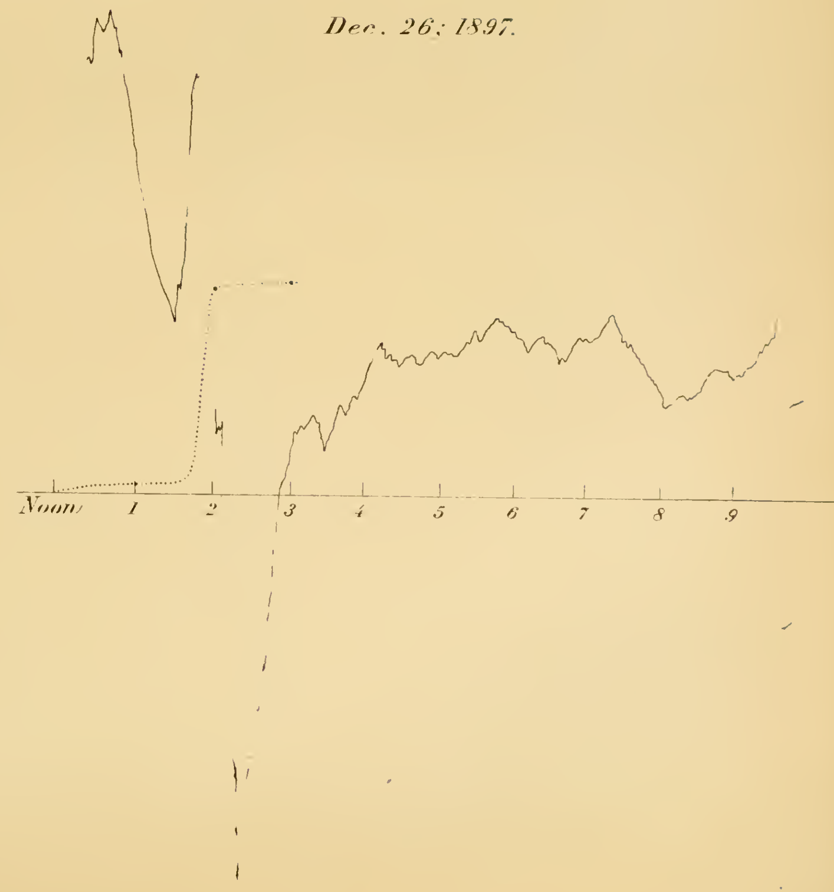


Fig. 9. *Dec. 26; 1897.*



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Experiments on the Magnetostriction of Steel, Nickel, Cobalt, and Nickel Steels.

By

H. NAGAOKA, Professor of Physics,

and

K. HONDA, Lecturer of Physics.

With Plates I—II.

§ 1. Introduction.

§ 2. Magnetization of steel, nickel, cobalt, and nickel steels.

§ 3. Apparatus for measuring change of length by magnetization.

§ 4. Change of length by magnetization in

- (a) Steel ovoid,
- (b) Nickel ovoid,
- (c) Cobalt (cast and annealed) ovoids,
- (d) Reversible nickel steel ovoids containing 46%, 36%, 29%, 25% of nickel,
- (e) Reversible nickel steel wires containing 45%, 35% of nickel in low fields.

§ 5. Effect of longitudinal stress on the magnetization of cobalt and nickel steels and the relations reciprocal with the change of length.

§ 6. Change of volume by magnetization in steel, nickel, cobalt, and nickel steel ovoids.

§ 1 Introduction.

In the course of our researches on magnetostriction[1] of different ferromagnetic bodies, questions of various character presented themselves, both with regard to the method of measurement and the nature of the sample. The minuteness of the effect called forth precautions against diverse sources of error, such as the non-homogeneity of the magnetic field, and the mechanical force arising therefrom, the non-uniformity of temperature, a slight disturbance of which was in most cases sufficient to mask the strain, which we were seeking after. All those different sources of error, however intricate they may at first appear, can, by properly arranging the measuring apparatus, be eliminated. The method of observing the change of length and of volume, which we have already described in our former papers, and the agreement of the results obtained in different experiments with the same sample will be a sufficient warrant for the soundness of the apparatus and the method of measurement.

Apart from such instrumentalities, the diversity in the character of magnetostriction with different samples is hardly to be avoided. Experiments by Rhoads[2] with rolled or stretched sheets of iron sufficiently prove how the treatment of ferromagnetic bodies has great influence on the change of length accompanying the magnetization. In our former experiment on the magnetostriction of iron, steel, and nickel, the soft iron was what may be practically considered homogeneous, but the nickel ovoid was turned into shape from a thick plate. It thus seemed advisable to repeat the experiments with more homo-

1) Nagaoka and Honda, Journ. Sc. Coll. **9**, 253, 1898; **13**, 57, 1900; **13**, 263, 1900.

2) Rhoads, Phys. Rev. **7**, 65, 1898; Phil. Mag. Nov., 1901.

geneous metals. In addition to this, our investigation did not include the magnetostriction in cobalt, the only specimen hitherto examined being an ovoid,[1] which was broken in two pieces, and firmly fixed together by wrapping thick paper over the broken edge. Unlike other experimenters, we tested cobalt in the present investigation in the cast and annealed states, and found an extraordinary difference in the change of length.

The curious property of *irreversible* nickel steel as regards magnetization was known for a long time by the beautiful experiment of Hopkinson. The question of magnetostriction in *reversible* nickel steels was a tempting subject for investigation, especially in connection with the remarkably small thermal expansion possessed by the metal, and its practical utility in the construction of scales and other instruments, which must not be affected by variations of temperature. Moreover it was very interesting to examine the nature of the magnetostrictions in nickel steel, as it is composed of two substances, whose length changes by magnetization are of opposite characters in weak fields, but similar in strong. A simple conjecture might suggest that the changes produced by magnetization are according to the relative proportion of the magnetostriction of the constituents, but the phenomenon is of a much complex character.

Associated with the changes of length and of volume, comes the Wiedemann effect, which is measured by the amount of torsion, caused by interaction of circular and longitudinal magnetizations. The measurement of the effect in cobalt must at present be postponed, as the metal can not be brought to a geometrical shape suitable for experiment, on account of its brittleness. Investigation of the effect in nickel steel of different percentages presents a phenomenon of the same

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1) Nagaoka, Wied. Ann. **53**, 487, 1894; Rapports presentés au Congrés de Physique, Paris **2**, 536, 1900. For literature on magnetostriction, see Rapports.

aspect, as for the length change, and the sense of twist is the same as that of iron in weak fields.

A singular characteristic of magnetostriction is its reciprocity with the effect of stress on the magnetization of different ferromagnetic substances. In the present instance, we have turned our attention especially to cobalt and nickel steels. As will be expected from the nature of the length change, the former metal is characterized by the existence of a minimum point closely analogous to that bearing the name of Villari for iron, while with the latter, the effect of the longitudinal pull always results in an increase of magnetization. The parallel statements giving the correlation between the magnetization and the torsion, first introduced by G. Wiedemann, can thus be extended to other effects of stress and the strain resulting from the magnetization.

The present paper is limited to the mere description of the experimental investigation, the theoretical discussion being reserved for future consideration.

§ 2. Intensity of Magnetization.

In all of our measurements, we noticed the change of dimensions by magnetization and the strength of the field H ($H = H' - NI$, where H' is the external field, N the demagnetizing factor, and I the intensity of magnetization). It will therefore not be out of place to make a digression on the magnetization of the ferromagnetic substances here examined, in order to enable us to examine the various changes considered as functions of the intensity of magnetization.

The following table gives the dimensions as well as the demagnetizing factor N of the ovoids examined in the present experiments.

a : Semi-minor axis of the ovoid.

c : Semi-axis of rotation of the ovoid.

v : Volume of the ovoid.

ρ : Density ,, ,, ,,

No.	Metal.	a (cm.)	c (cm.)	v (c.cm.)	ρ	N
1	steel	0.493	10.00	10.40	7.85	0.0836
2	nickel	0.493	10 00	10.40	8.87	0.0836
3	cast cobalt	0.493	10.00	10.38	8.26	0.0836
4	annealed cobalt	0.495	10.02	10.52	8.20	0.0836
5	nickel steel (46% Ni)	0.494	10.01	10.45	8.15	0.0836
6	,, ,, (36% Ni)	0.496	10.01	10.48	8.11	0.0836
7	,, ,, (29% Ni)	0.492	10.01	10.43	8.12	0.0835
8	,, ,, (25% Ni)	0.494	10.02	10.40	8.05	0.0836

The difference in the volume of the ovoids is to be attributed to the slight deviation from the exact geometrical shape.

As most specimens of cobalt contain more or less nickel, the cast and the annealed samples of the metal were subjected to chemical analysis, with the following results, for which our thanks are due to Mr. T. Suzuki, student in the chemical department of the University.

Cast cobalt.		Annealed cobalt.	
Co	93.36	Co	92.74
Ni	5.05	Ni	4.07
Fe	1.20	Fe	1.07
C	1.38	C	1.64
Si	0.39	Si	0.28
Cu	0.17	Cu	0.15
Mn	0.12	Mn	0.04

The specimen is not very pure, containing a small percentage of nickel as an impurity.

The magnetization was magnetometrically determined with the following results:—

Steel. (cast)		Nickel.		Cobalt. (cast)	
H	I	H	I	H	I
0.8	44	1.0	14	2.7	30
1.3	135	2.7	76	5.6	83
1.6	319	5.5	139	14.7	274
3.1	633	7.8	198	19.4	340
7.4	878	11.7	252	30.0	467
23.0	1122	18.2	314	44.7	572
140.0	1433	33.3	377	89.8	778
302.0	1555	59.9	426	256.3	984
511	1627	115.9	459	473.6	1080
598	1644	482	484	643	1119
672	1648	796	486	720	1136

Cobalt. (annealed)		Nickel steel (46%).		Nickel steel (36%).		Nickel steel (29%).	
H	I	H	I	H	I	H	I
3.6	4	0.9	36	1.7	38	1.2	24
13.4	22	2.7	102	4.8	134	2.6	81
22.4	38	4.2	241	9.4	352	6.4	139
42.6	90	6.2	465	14.6	524	13.3	188
77.5	188	16.9	926	30.4	720	24.7	224
194.9	367	35.5	1108	85.5	900	46.2	243
281.0	439	119.7	1274	150.1	934	68.8	249
364.3	527	231.3	1303	261.5	953	140.2	256
460.8	568	380.0	1323	367.4	962	324.7	264
617	633	557	1333	510	971	575	273
788	699	778	1345	818	992	893	280

The curves of magnetization are represented in Fig. 1, Pl. I. The most magnetic of the ferromagnetic metals here examined is cast steel, whose magnetization comes very near to that of soft iron. Of the two kinds of cobalt, the cast specimen is nearly midway between steel and nickel ; but with annealed specimen, the susceptibility is small in weak fields, and less than in nickel, but the differential susceptibility $\left(\frac{dI}{dH}\right)$ is greater in the strong, so that the intensity of magnetization becomes ultimately greater than in nickel.

Of the three kinds of reversible nickel steels, the 46% Ni specimen approaches steel, the 36% Ni lies near cast cobalt, and the 29% Ni is less magnetic than pure nickel. The magnetization reaches asymptotic value in fields less than those for steel or cobalt. The 25% specimen is only feebly magnetic, so that its magnetization is scarcely to be detected by the magnetometer. There we notice the singular fact, that the intensity of magnetization in nickel steel is not proportional to that of the constituent metals.

§ 3. Description of the Apparatus for Measuring Changes in Length.

The vertical and horizontal projections of the apparatus are represented in Figs. *a* and *b*. The essential part consists of a stout

Fig. *a*.

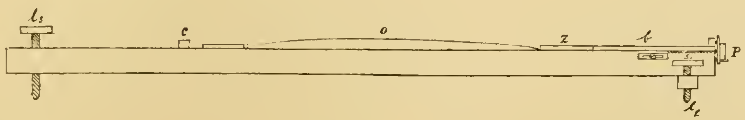
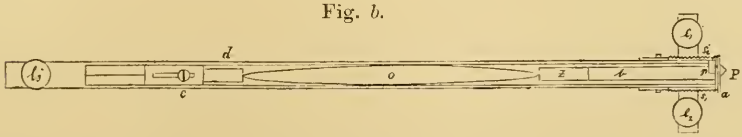


Fig. *b*.



brass bar 53 cm. long, 1 cm. broad, and 1.1 cm. high. It is provided with three levelling screws l_1 l_2 l_3. A carefully polished V-groove is

cut along the bar ; the groove is slightly widened at the middle of the bar, so as to allow the ovoid o to be so placed that the line of its axis passes through the centre of the optical lever (a). A small rectangular brass pillar p is erected at one corner of the bar. A small vertical V-groove is cut in it, and on this two points of the optical lever rest. The lever is a small rectangular piece of brass with three steel points, of which two rest on the pillar p, and the remaining one is in the same line as the axis of the ovoid, and rests on small plane glass plate, which is fixed to the end of the movable brass rod b. The lever arm is equal to 1.168 mm. Preliminary testing showed that the relative positions of these three steel points were not directly affected by the magnetizing force. The lever is pulled on both sides by small spiral springs of hard brass wire. These springs can be adjusted by slide arrangements, so that the lever turns its two points about on p, without being pushed out by the displacement of the ovoid. The reflecting face of the prism P attached to the lever was silvered. The greatest difficulty in the measurement of change of length by magnetization arises from the temperature changes produced by the magnetizing current. The temperature effect can, however, be greatly compensated for by applying the principle of the gridiron pendulum. This end was achieved by using zinc rods of suitable length, so that, in any combination, the total expansion due to small changes of temperature in particular lengths of zinc and the ovoid was equal to that in a particular length of brass. Zinc rods 5 mm. thick were carefully turned on a lathe and cut into proper lengths.

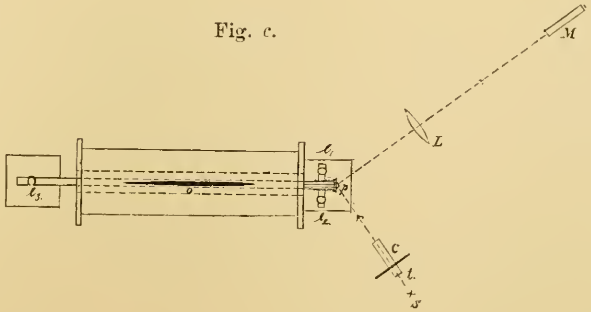
A brass rod (b) 5 mm. thick is placed in contact with the zinc rod (z). At the end of the brass rod, a plane glass plate is attached, so that the steel point of the lever comes in contact with it. At the other extremity of the row of rods and the ovoid is a stop. It consists of a triangular prism of brass to which a brass rod (d) 5 mm. thick is

attached. The prism fits in the V-groove, and is fixed tightly by means of a clamping screw c. To adjust the length bc, it is provided with a slit g. The screw c can be fixed at any part of the slit, and the position of the movable system can be so adjusted that the plane of the lever is perpendicular to the axis of the system. The slight push exerted by the springs s_1 s_2 on the movable system prevents the play of different parts among one another, and was sufficient to overcome friction during the displacement of the system.

The ovoid was placed inside a solenoid 30 cm. long, which lay in a horizontal position magnetic east and west. The resistance of the solenoid was 0.63 Ω, and gave a field of 37.97 C.G.S. units for a current of one ampere. The internal diameter of the solenoid was 3.2 cm. and no part of the measuring apparatus came in contact with it. Care was taken to place the apparatus along the axis of the solenoid, and so to place the ovoid that its centre coincided with that of the solenoid.

The optical arrangement for measuring the change of angle of the optical lever is shown in Fig. c. A fine glass thread t is placed

Fig. c.



vertically in the focus of a collimator c, and illuminated by a gas lamp. The ray after passing the lens, is reflected by a right angled prism p attached to the lever. The ray then traverses an achromatic lens L (focal length$=$66.95 cm.). The image of the glass thread is

then observed by means of a microscope provided with micrometer ocular. By using filar micrometer, the accuracy of the measurement may be increased several times, but it was found quite superfluous. One division of the micrometer, the tenth of which can be easily estimated, was equivalent to an elongation of 4.35×10^{-7}.

Fig. *c* shows the horizontal plan of the arrangement while the perspective view is given in Fig. *d*.

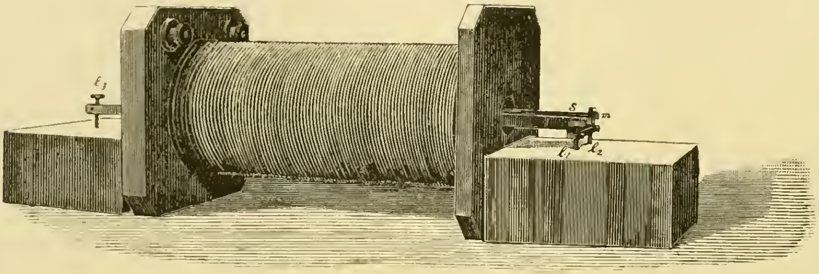


Fig. *d*.

§ 4. Change of Length in Different Ferromagnetic Bodies.

We consider the different sorts of iron, which were examined in our former experiments as homogeneous, as the general character of the change is both qualitatively and quantitatively nearly alike, and they are always subject to very careful annealing. Any new experiment would therefore have been superfluous.

(*a*) Cast Steel (Fig. 2, Pl. I.).

Dr. H. du Bois was kind enough to give us a piece of cast steel, which was regarded as the most homogeneous specimen at present obtainable. The rod was turned into an ovoid and its change of length measured in the usual manner with the following result.

H	$\frac{\delta l}{l}$
1.9	0.39×10^{-6}
3.2	0.61
14.8	1.79
26.3	2.53
122.6	1.53
247.2	−0.44
451.0	−3.96
676.5	−6.10
919	−6.80
1389	−7.75
1739	−8.28

In low fields, the length increases and at last reaches a maximum, whence it gradually diminishes, till it indicates no elongation. The decrease goes on steadily, but the rate of change becomes gradually less, and at last assumes an asymptotic value. As will be seen from the graphical representation (Fig. 2), the general feature of the curve representing the length change resembles that for iron, with slight difference in quantitative details.

(*b*) Nickel (Fig. 2, Pl. I.).

The nickel ovoid, which we have formerly used for the measurement of length and volume changes, was prepared from a thick plate of the same metal. Although the ovoid was annealed in charcoal fire for several days, lack of homogeneity was undeniable. To guard against such mischances, we have tested a new specimen, supplied by Johnson and Matthey, turned in the form of ovoid from a cylindrical rod.

The nature of the change does not materially vary from the

former specimen. In weak fields, the contraction takes place at first slowly, but gradually at an increased rate. Between fields 5 and 100, the rate of the diminution is very rapid. but the change becomes at last asymptotic, when it amounts to about 38×10^{-6}. It appears from the curve that the diminution of length will be but slight even if the field be increased to several thousand units. The following table gives the observed changes of length.

H	$\frac{\delta l}{l}$
3.9	-1.1×10^{-6}
9.8	-5.2
22.8	-13.1
42.6	-20.8
72.1	-26.2
127.8	-30.9
238.6	-33.8
473.0	-35.3
794.0	-35.7
1171	-36.1
1508	-36.5
1881	-36.9

(*c*) Cobalt (Fig. 2, Pl. I.).

One of us has already examined the change of length in cobalt ovoid, which unfortunately was broken in two pieces. The result was, notwithstanding, in conformity with that already discovered by Bidwell.

Rods of cobalt, obtained from Johnson and Matthey, were turned

into ovoids of the same dimensions as for the two former metals. One of the ovoids was examined in the state, in which it issued from the lathe, while the other was annealed in charcoal fire for about 4 hours, after being carefully wrapped in asbestos paper. As the change of length by magnetization and the intensity of magnetization were characterized by a remarkable difference in character, it would be well to describe the phenomena separately for cobalt ovoids, which underwent different treatments.

Cast Cobalt. The behaviour of cast cobalt, as regards the length change, is similar to that in nickel in weak fields. Instead of reaching an asymptotic value as in nickel, the contraction of cobalt reaches a maximum at about $H=160$, from which the metal gradually recovers with increasing fields, till it attains its initial length in $H=750$. The metal however goes on elongating, but at a less rapid rate, till $H=2000$, which is the strongest field employed in the present experiment.

H	$\frac{\partial l}{l}$	H	$\frac{\partial l}{l}$
12.0	-0.78×10^{-6}	643.3	-0.87
19.4	-1.53	735	-0.13
29.1	-2.62	1114	$+2.83$
49.6	-5.14	1464	$+4.11$
76.3	-7.11	1807	$+5.14$
166.3	-8.11		
332.5	-6.28		
501.4	-3.36		

The table gives the observed changes; representing the change by means of a curve (Fig. 2), we notice a singular

trend, somewhat resembling the inverted form of the curve showing the same change for iron and steel. If the existence of the maximum elongation in iron warrants the existence of the Villari point, a point of opposite character must exist in cobalt if the metal be subject to loading.

Annealed Cobalt. The cast cobalt has silvery hue, similar to nickel, only lacking the yellowish lustre of the latter. By annealing cobalt, the surface colour turns ashy gray, and the permeability of the metal diminishes in a remarkable degree, as will be seen from the curves of magnetization (Fig. 1). The change of length by magnetization takes place at first slowly, but goes on steadily increasing till it amounts to nearly 25×10^{-6} in $H=2000$. The observed values are as follows :—

H	$\frac{\delta l}{l}$
12.6	-0.04×10^{-6}
39.8	-0.09
59.6	-0.13
92.0	-0.48
204.3	-2.14
458.0	-5.67
772	-11.33
1150	-17.44
1465	-20.71
1905	-25.06

The curve representing the change is therefore very simple, approximating to a straight line. As will be found later on, we found the reciprocity between the strain and the effect of stress again

established, since the longitudinal pull only produces diminution of magnetization.

(*d*) Reversible nickel steels (Fig. 3, Pl. I.).

The beautiful experiment of Hopkinson revealed a singular property of irreversible nickel steel as regards magnetization. The discovery of reversible nickel steel called forth new demands for the metal on account of its practical utility. Among the various physical properties of nickel steel, the small thermal expansion claims a prominent position in the different applications of the metal, such as for the construction of scales, or the compensation of chronometers and others of similar nature. Unfortunately no investigation has as yet been made appertaining to the deformation of the metal by magnetization.

Through the kindness of Messrs. Guillaume and Dumas, who supplied us the different samples of nickel steels, manufactured by Commentry-Fourchambault and Decazeville, we were enabled to examine the magnetostriction of the reversible nickel steel in its various aspects.

The samples to be tested were either turned into ovoids of the same dimensions as for the other metals, or used in the form of wires. These two different sets of metals do not show serious discrepancies in the observed results, which are given below for specimens containing different percentages of nickel, either in the form of ovoids or wires. It is to be remarked that the annealing of nickel steel wires was conducted in a glass tube, through which hydrogen gas was kept in constant circulation, and heated to 500° C. for more than three hours.

The observed changes of length are given in the following tables :—

Nickel steel ovoids.

46%		36%		29%	
H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$
4.0	0.08×10^{-6}	7.5	0.44×10^{-6}	1.2	0.04×10^{-6}
4.6	0.22	17.6	2.00	15.0	0.13
6.7	0.87	37.1	5.05	27.8	0.87
10.6	2.61	66.5	8.62	45.3	1.13
32.2	9.67	151.5	12.32	81.8	1.70
71.4	15.89	234.0	13.72	135.7	2.26
121.2	18.72	341.2	14.80	292.2	3.57
314.2	22.29	400.8	15.15	509.7	5.49
573.1	23.30	587.1	16.24	864	8.62
860	23.91	1050	18.29	1238	12.19
1508	24.78	1342	19.81	1622	15.20
1908	24.99	1905	22.12	2040	18.55

Nickel steel wires.

45% (annealed)		45% (unannealed)		35% (annealed)		35% (unannealed)	
H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$
2.6	0.93×10^{-6}	11.8	0.34×10^{-6}	3.3	0.29×10^{-6}	5.1	0.12×10^{-6}
6.2	3.49	22.9	1.22	12.2	4.20	14.7	0.34
11.7	7.36	30.7	1.68	21.8	6.93	29.8	0.84
21.2	11.78	61.4	4.25	30.9	8.70	50.5	1.80
30.5	14.51	98.7	6.77	66.5	11.35	108.6	4.20
61.2	18.76	145.5	9.34	109.7	12.19	205.7	7.31
182.9	22.04	337.8	14.76	238.5	13.26	471.1	11.77
404.5	23.05	508.7	16.40	510.0	14.70	647.7	13.78
711	23.56	817	17.58	827	16.30	701	14.37
933	23.64	1246	18.09	1407	18.49	1033	16.55
1499	24.28	1485	18.51	1541	19.83	1509	18.99
1901	24.49	1831	18.84	1928	21.76	1846	21.09

The curves of the length change are plotted in Fig. 3.

All the nickel steels indicate increase of length in fields up to about $H=2000$. The character of the change for 46% Ni resembles that for nickel with opposite sign, inasmuch as the curve of elongation has great similarity to that of magnetization. The elongation in very weak fields takes place slowly, but in fields of about 30 units, the rate of change is most rapid and soon reaches an inflexion point, after which the increase in length takes place only very slowly and in an asymptotic manner.

With the 36% Ni, we observe similar features in the curve of elongation. The inflexion point lies in higher field, but the elongation is less than in 46% alloy. After this stage is passed, the ovoid goes on increasing in length at an almost constant rate, which is greater than for 46% Ni. Although the field, at which the curves for 46% and 36% Ni intersect has not yet been reached, we can easily infer that if the field be sufficiently increased, the elongation in 36% Ni, which is the least expansible by rise of temperature, will exceed that for 46% Ni. The contrast between 46% and 36% Ni is similar to that between 36% and 29%, so that what has already been remarked with respect to the two former alloys, equally applies to the relation between the two latter metals. It is also remarkable to observe that the 29% Ni, which will apparently indicate the largest increase in length, if the field be made sufficiently strong, is the least susceptible of the three nickel steels. With the 25% Ni, we could not detect any change, which is within the scope of measurement now attainable with the present arrangement.

The nickel steel wires, in the annealed state, present changes in length as similar to those of the ovoids. In the hard drawn state, the change is decidedly less than in the annealed.

The curves of the length change in iron or nickel, placed side by side with those in nickel steel, present a singular contrast. As is well known, nickel contracts, instead of expanding as in iron, the amount of contraction being several times that of iron. The feature here presented by nickel steel is similar to nickel as regards the amount and the character of the change, but as to the sense of elongation, it is similar to iron in weak fields increasing instead of diminishing as in nickel. It thus appears that the length change by magnetization is not of a simple nature, and not to be easily determined from the percentages of the constituent metals.

(*e*) Nickel steel wires in low fields (Fig. 4, Pl. I.).

Urged by the question of the practical utility of the metal, we made special investigations into the change of length in low fields, such as may habitually occur in the neighbourhood of electric installation or in terrestrial magnetic field. The question will be of utmost utility in deciding the effect of the terrestrial field ; as one instance, we may mention that in using Jäderin's wires of nickel steel in geodetic measurements. One may wonder from what has already been described, if the effect of the magnetic field will not be of the same magnitude as that of thermal expansion, which, as is well known, is of very minute amount. Our results for low fields are as follows :—

45% Ni (annealed)		45% Ni (unannealed)		35% Ni (annealed)		35% Ni (unanneald)	
H	$\frac{\partial l}{l}$	H	$\frac{\partial l}{l}$	H	$\frac{\partial l}{l}$	H	$\frac{\partial l}{l}$
3.5	1.18×10^{-6}	8.0	0.01×10^{-6}	3.5	0.50×10^{-6}	9.0	0.04×10^{-6}
7.6	4.22	11.0	0.17	5.2	1.56	11.7	0.21
11.7	6.64	15.7	0.62	8.9	3.12	14.5	0.32
14.7	8.40	19.7	1.07	15.8	5.23	18.2	0.63
21.0	10.60	21.7	1.09	21.2	6.60	22.0	0.77

From the above table, we gather the fact that the magnetostriction plays no important part in the use of nickel steel scales ; only in measurements of extreme accuracy, it will be necessary to add a very small factor of correction to the measured values, according as the scale is placed in the magnetic meridian or perpendicular thereto. As will be seen from the curves of elongation (Fig. 4), the difference in a metre will generally be less than $\frac{1}{10}\mu$ for measurements made in the said directions.

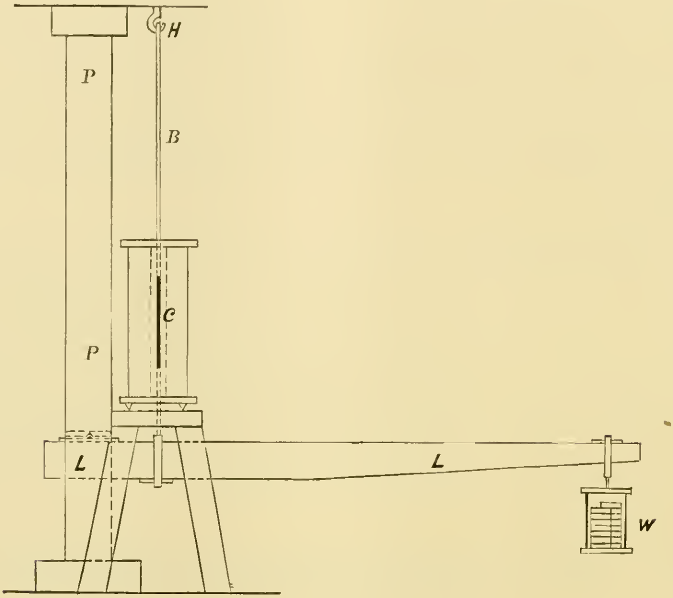
One distinct feature of the curves of elongation is the effect of annealing. In both 45% and 35% Ni, the wire elongates several times more in the annealed than in the hard drawn state, so that in cases when the change caused by magnetization is to be feared, we shall be able to eliminate the errors due to magnetostriction in a considerable degree by using the unannealed metal.

§ 5. Effect of Longitudinal Stress on Magnetization and the Reciprocal Relations.

A remarkable feature of magnetostriction is the reciprocal relation between the strain caused by magnetization and the effect of stress on magnetization. We have already examined the different changes from this stand-point for iron and nickel, and found that the relations between strain and stress are generally reciprocal in these two metals. In the present experiment, we made special examination into the effect of longitudinal pull on the magnetization of cobalt and nickel steels in the same light.

The annexed diagram shows the scheme of arrangement for examining the effect of pull on magnetization. A wooden lever *LL*, furnished with a knife edge, rested horizontally against a vertical pillar *PP*. The lever arm held a brass rod *B*, hang by a hook *H* from the ceiling ; a cobalt cylinder *C* (length 27.3 cm., diameter 1.36 cm.)

was brazed to the rod and placed axially in the interior of the magnetizing coil, which was placed vertically on a separate tripod stand.



The other end of the lever was loaded by the weight W. The change due to longitudinal stress was measured by means of a magnetometer.

In weak fields, the magnetization of cast cobalt decreases by loading. As the field strength is increased, the amount of the decrease reaches a maximum and then gradually lessens. Ultimately the field where the longitudinal pull does not affect the magnetization is reached. When this stage is passed, the magnetization increases by loading, so that the effect is reversed. The existence of a critical point in cobalt analogous to that of Villari in iron is thus established (Fig. 5, Pl. I.).

With annealed cobalt, the effect is simpler. As will be seen from the curves in Fig. 5, the longitudinal pull always causes a diminution of magnetization, which increases with the field. Thus the

behaviour of cast and annealed cobalt stands in reciprocal relation with that of the change of length produced by magnetization, as will be clear in the following parallel statements.

Cast cobalt.

Magnetization produces diminution of length in low fields, which after reaching a maximum gradually lessens, and finally produces increase in strong fields.

Mechanical elongation produces diminution of magnetization in low fields, which after reaching a maximum gradually lessens, and finally produces increase in strong fields.

Annealed cobalt.

Magnetization produces diminution of length, which gradually increases with the strength of the field.

Mechanical elongation produces diminution of magnetization, which gradually increases with the strength of the field.

The effect of mechanically elongating nickel steel always results in the increase of magnetization, as will be seen in Fig. 6, Pl. II. The change caused by stretching depends on the strength of the field, and is generally greater in the weak than in the strong. The correlation between the elongation due to magnetization and the effect of stretching on magnetization may be expressed in following words.

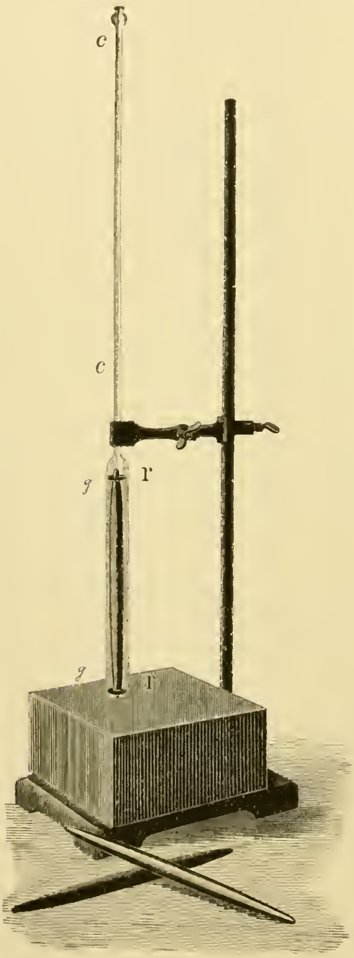
Magnetization produces increase of length in nickel steel.

Mechanical elongation produces increase of magnetization.

§ 6. Change of Volume by Magnetization.

In spite of the well known experiments of Joule showing that iron does not change in bulk by magnetization, experiments by Knott, and ours sufficiently prove that this is by no means the case. It was suggested by Rhoads, that the change of volume may in a great part be due to the heterogeneity of the material under examination, while in some the arrangement of the experiment was not

free from errors, which, though very small, were sufficient to disguise the minute effect. One serious drawback in these experiments is the use of an unproportionally large mass of iron, which if the ratio of dimensions be sufficiently great, would not have been altogether objectionable, but as it generally happened to be, did not give the expected result. Non uniformity of the field is another source of error, which unfortunately has been too often neglected ; the result obtained in fields, which are not uniform, will indeed be very difficult of interpretation. If the material under test be not placed axially in the direction of magnetization, and the mechanical force urging the magnetic substance in one or other direction, comes into existence, the change of shape of volumenometer will in some cases be of such an amount, that it not only diminishes the measured change, but screens the desired effect. These various sources of error may, by proper construction of the volumenometer, be easily eliminated.



The accompanying cut, taken from a photograph, shows the arrangement of the volumenometer, which we have used in our observations. Into a glass tube *gg*, to which is hermetically sealed a capillary tube *cc* of about 0.4 mm. internal diameter, fit two brass rings *rr*. These rings are partly open, and by the elastic force, fit the tube quite tightly. The extremities of the ovoid

project out of the openings, and its axis is kept in coincidence with that of the tube. The axis of the magnetizing coil, which is all the while water jacketed, also coincides with that of the volumenometer during the experiments, so that the effect of the mechanical force and the non-uniformity of the field (the length of coil being 30, while that of the ovoid is 20 cm.) will not enter the measured results.

The motion of the capillary meniscus was noted by means of a microscope provided with a micrometer ocular. The magnifying power of the microscope was generally so chosen, that the range of motion during the experiment lay within the field of view. Although the magnetizing coil was water jacketed, the lack of temperature compensation, as in the experiments on the length change, made it desirable to notice the motion of the liquid shortly after making the current. In some of the metals, the change was generally almost instantaneous, but in a few specimens we noticed a distinct time-lag.

As announced by Quincke,[1] change of volume in the liquid filling the volumenometer may be caused by the pressure in the magnetic field. To guard against this point, we have specially examined the volumenometer readings by simply filling it with water or ferric chloride, and did not find the effect within the range of field used in the present experiment, as might well be expected, as the pressure is proportional to the square of the field strength.

Cast Steel. The metal shows increase of volume in fields up to about 2000. The following gives the measured change.

1) Quincke, Sitzungsberichte d. Berliner Akademie d. Wissenschaften, 20, p. 391, 1900.

H	$\frac{\delta v}{v}$	H	$\frac{\delta v}{v}$
1.8	0.01×10^{-6}	346.3	0.18
2.6	0.02	774	0.32
9.1	0.06	1028	0.42
36.8	0.14	1344	0.57
142.4	0.16	1729	0.80

In weak fields, the change is very small, but the rate is tolerably large ; as the field increases, the curve (Fig. 7, Pl. II.) reaches an inflexion point. The change goes on somewhat slowly for fields amounting to a few hundred units ; it again reaches an inflexion point, whence to increase steadily and almost at a constant rate as the field is further increased.

Nickel. In our two former experiments, we noticed a discrepancy in the nature of the volume change in this metal. With a bar of square section, we noticed a diminution, while an ovoid showed an increase. How this may be easily accounted for, we have already discussed in our former paper, so that it will be now unnecessary to take up the subject anew.

With the present specimen, which may be regarded as the more homogeneous, we noticed a slight increase of volume, which is of about the same amount as that observed in the former experiments.

The character of the change is similar to that in steel, the curve (Fig. 7.) of the change presenting two inflexional points. These points do not appear in such a remarkable degree as in steel, but their where abouts can be ascertained at a glance. The observed changes in volume are given below :—

H	$\frac{\delta v}{v}$
10.4	0.00×10^{-6}
16.5	0.01
27.5	0.02
53.7	0.03
124.9	0.04
384.6	0.07
638	0.10
1052	0.13
1539	0.16
1983	0.22

Cobalt. (Fig. 7.) Just as we have noticed a difference in the length change and the intensity of magnetization in the cast and annealed metals, we notice a difference in the volume change for these two bodies.

The behaviour of cobalt is unlike other ferromagnetic substances; instead of showing increase, the magnetization causes diminution of volume, which in the annealed state bears close resemblance to the character possessed by nickel, indicating glimpse of two inflexion points in the curve of volume change. With the cast specimen, this feature is still more different from the other ferromagnetic substances. The diminution of volume takes place quite rapidly in weak fields, so that the curve soon reaches an inflexion point. The rate of diminution after passing this point is very small, the curve passing on almost parallel to the axis of the field. This state prevails in a large range of fields, but the curve, in place of showing another inflexion point, reaches a point of maximum diminution

of volume. The course of the curve turns and proceeds in the same direction as far as the present experiment goes. This character is possessed by cast cobalt only among the numerous specimens of ferromagnetic substances hitherto experimented upon. Further we may notice that the amount of the change is, to a certain extent, greater in cobalt than in iron, steel, or nickel.

The results of measurements in cobalt are given below :—

Cast cobalt.		Annealed cobalt.	
H	$\frac{\delta v}{v}$	H	$\frac{\delta v}{v}$
12.4	-0.07×10^{-6}	28.7	-0.02×10^{-6}
19.1	-0.17	41.9	-0.04
24.1	-0.27	58.1	-0.06
72.2	-0.83	90.4	-0.08
162.3	-1.17	204.2	-0.27
378.5	-1.35	468.8	-0.60
665	-1.50	800	-1.09
1068	-1.55	1127	-1.58
1457	-1.47	1473	-1.84
1889	-1.38	1916	-2.10

Nickel steel. (Fig. 8.) The volume change in nickel steel is characterized by the simplicity and the large amplitude of the effect.

The following table gives the measurements made on three specimens of nickel steels containing different percentages of nickel.

46% Ni.		36% Ni.		29% Ni.	
H	$\frac{\delta v}{v}$	H	$\frac{\delta v}{v}$	H	$\frac{\delta v}{v}$
68.1	0.03×10^{-6}	7.6	0.03×10^{-6}	6.5	0.06×10^{-6}
284.5	0.42	11.8	0.05	25.7	0.71
386.1	0.60	30.8	0.24	62.4	1.49
592.0	1.13	93.5	0.87	113.6	2.91
679	1.28	209.1	2.35	227.5	6.52
893	1.59	309.0	4.28	425.2	12.49
994	2.19	682	9.10	659	20.30
1327	3.00	1042	14.25	989	29.7
1452	3.55	1333	18.44	1260	38.7
1618	4.38	1669	22.99	1687	51.1

The common feature of the change is the approximate proportionality of the effect to the magnetizing force.

The amplitude of the change is, however, not directly proportional to the intensity of magnetization, as the 46% Ni shows a smaller effect than the 29% Ni, which is the least magnetizable among the samples, with the exception of the 25% Ni, whose magnetization is scarcely to be detected by ordinary means. In fields of 1600 C.G.S. units, the change amounts to

$$\begin{aligned}\frac{\delta v}{v} &= 4.2\times10^{-6} \quad \text{for } 46\%\ \text{Ni}\\ &=22.0\times10^{-6} \quad \text{,, } 36\%\ \text{Ni}\\ &=48.7\times10^{-6} \quad \text{,, } 29\%\ \text{Ni}\\ &= 0.2\times10^{-6} \quad \text{,, } 25\%\ \text{Ni}\\ &= 1.2\times10^{-6} \quad \text{,, soft iron.}\end{aligned}$$

The difference between steels containing different percentages of

nickel is indeed remarkable, as the changes here noticed far exceed those hitherto observed in simple ferromagnetic substances. The change in 29% Ni is nearly 40 times greater than in soft iron; in fact, the motion of the capillary meniscus could be easily followed by the naked eye, as the displacement, which took place almost instantaneously with the making of the current, was nearly 5 mm. in the strongest field at our disposal. Even the 25% Ni sample showed a volume change, which, in spite of the minute magnetizability, could be distinctly measured by a microscope.

From the above result, it follows that there is a certain alloy, whose percentage content of nickel will lie somewhere between 25% and 36%, which will indicate the greatest change of volume; the change will indeed be the greatest, that we can observe in the ferromagnetic substances of common occurrence.

When we consider the magnitude of the volume change in nickel steels and compare it with that observed in iron or nickel, we are struck with the immensity of the effect, which is not shared in such an extraordinary degree by either of the constituents of the alloy. The same remark applies to the magnetizability of the samples. That the alloy of two strongly magnetizable substances should give rise to an almost neutral body is in no way an object of curiosity, when considered in the same light as the enormous effect of magnetization on the bulk of the alloy. In the present instance, we are at a loss to decide which of the two metals plays a predominating part in the magnetostriction of nickel steel; perhaps a complete study of the subject from the lowest percentage to the pure nickel, and the comparative investigation of the phenomena in the succeeding stages will reveal to us the groupings of the constituent metals while entering into an alloy, as well as the part played by them in the magnetization and in the various phenomena attending it.

It may at first sight appear that the smallness of the thermal expansion in nickel steel necessarily entails the minuteness of the change of length and of volume, but no connection seems to exist between the magnetostriction and the deformation due to temperature variation, as illustrated in the preceding experiments.

§ 7. Wiedemann Effect in Nickel Steel.

As closely allied to the change of volume and of length, the Wiedemann effect comes into our consideration as due to magnetostriction. Unfortunately we could not investigate the phenomenon in cobalt for want of material of geometrical shape, suitable for the investigation. The results for iron, steel, and nickel have been already described in our former paper, so that we shall consider only nickel steels, which have not yet been investigated.

The effect was measured in the usual way by suspending the wire vertically in a magnetizing coil, and by passing an electric current of known strength, the angle of torsion due to the combined action of circular and longitudinal magnetizations was measured by the rotation of a fine mirror attached to the end of the wire. The vertical component of the terrestrial magnetic force was compensated for by another coil inserted within the coil. The wire was of such length (21 cm.) that the magnetic field was practically uniform throughout. For the different sorts of wires tested, we are indebted to Mr. Ch. Ed. Guillaume.

The measured angles τ of torsion per cm. in seconds of arc are given for different samples of wires in the following table :

45% nickel steel. (annealed) $c=134.0 \left(\frac{\text{amp.}}{\text{cm}^2.}\right)$		39.2% nickel steel. (unannealed) $c=371.5 \left(\frac{\text{amp.}}{\text{cm}^2.}\right)$		23.6% nickel steel. (unannealed) $c=310.0 \left(\frac{\text{amp.}}{\text{cm}^2.}\right)$	
H	τ	H	τ	H	τ
0.8	8.3″	7.3	7.6″	4.9	0.7″
2.8	15.7	23.5	20.4	17.0	2.8
4.0	23.1	50.6	21.8	37.6	6.6
8.1	32.3	81.8	17.9	85.0	6.9
26.7	25.9	117.0	14.7	135.6	4.6
44.5	18.0	322.0	6.4	367.0	1.1
104.0	6.0	452.6	4.1	589.3	0.0
283.2	−1.6	742	2.3	873	−1.4
937	−4.6	1104	1.6	1230	−2.1
1522	−4.9	1531	1.6	1350	−2.1

The direction in which a nickel steel wire twists is the same as in iron. If the north pole of the wire suspended vertically be at the free end, and the direction of the current traversing the wire be downwards, the torsion of nickel steel seen from above is in the direction of the hands of a watch.

The amount of torsion (Fig. 9.) increases with the magnetic field, but it soon reaches a maximum, to decrease afterwards quite slowly as the field becomes stronger, and the torsion of the wire is reversed in strong fields. With the samples tested, the torsion increases with the percentage of nickel. The 23.6% Ni and 39.2% Ni samples were examined in a hard drawn state; but the 45% Ni wire was examined after annealing it in hydrogen, as already described.

§ 8. Summary of the Results.

The results obtained in the present investigation can be summarised in the following statements.

Magnetization.

1. The magnetization of cast cobalt is different from that of the annealed metal, the latter being only about half as magnetizable as the former. The magnetization of cobalt in the annealed state is characterized by its high differential susceptibility in strong fields.

2. The magnetization of 46% nickel steel is between iron and cobalt, while that of the 36% Ni is nearly the same as in cobalt. The 29% Ni is nearly half as magnetizable as nickel, and the 25% Ni is only feebly magnetic. The course of the magnetization curve in nickel steel resembles that in nickel.

3. (*a*) In cast cobalt, mechanical elongation in the direction of magnetization produces diminution of magnetization in low fields, which gradually lessens as the field strength is increased. Ultimately there is increase of magnetization by elongation. Thus, there is a critical point in cobalt, which has a character opposite to that bearing the name of Villari in iron.

(*b*) In annealed cobalt, mechanical elongation in the direction of magnetization produces diminution of magnetization, which increases with the field.

4. Mechanical elongation in the direction of magnetization produces increase of magnetization in nickel steel.

Change of Length by Magnetization.

1. The quality of the change is not seriously affected by the small non-homogeneity of the sample.

2. In cobalt, the character of the change is different in the cast and in the annealed state.

(*a*) Cast cobalt contracts in low fields and attains the minimum length in $H=130$, whence it returns to its former length in $H=750$, and goes on elongating at a slow rate, as the field is increased (result already obtained by Bidwell). This stands in reciprocal relation with the effect of mechanically elongating cast cobalt on magnetization.

(*b*) Annealed cobalt contracts without showing a minimum length up to $H=1800$. The character of the change is similar to that of iron after passing the maximum elongation. This stands in reciprocal relation with the effect of mechanically elongating annealed cobalt on magnetization.

3. Nickel steel elongates by magnetization. The character of the change is similar to that of nickel, but the sense is different. The rate of change $\left(\frac{de}{dH}\right)$ in high fields is greater in 29% Ni than in 36% Ni, in which it is again greater than in 46% Ni. The amount of the change is in inverse order up to $H=2000$.

Nickel steel elongates to a greater degree in the annealed than in the hard drawn state.

4. The elongation of nickel steel in very low fields (comparable with the terrestrial magnetic field) is generally less than 10^{-7}.

Change of Volume by Magnetization.

1. Iron, steel, and nickel show increase of volume by magnetization, but cobalt (cast and annealed) shows contraction.

2. (*a*) Cast cobalt contracts at a rapid rate in low fields, but above $H=100$, the rate becomes less and the contraction reaches a maximum in $H=900$, whence to return gradually with further increase of the field.

(*b*) Annealed cobalt contracts in volume at a steady rate as the field is increased. The contraction becomes ultimately greater than in cast cobalt.

3. The increase of volume in 46% Ni, 36% Ni, and 29% Ni steels takes place almost proportional to the strength of the field. The amount of the increase becomes greater as the percentage of nickel becomes less. The volume change in 29% Ni is the greatest that has ever been observed, and is nearly 40 times that in iron in strong fields.

Wiedemann Effect.

The torsion produced by the combined action of circular and longitudinal magnetizations in nickel steels increases with the longitudinal field and reaches a maximum whence to decrease gradually as the field is further increased. In some specimens, the torsion ultimately takes place in the opposite direction. The direction in which nickel steel twists is the same as in iron.

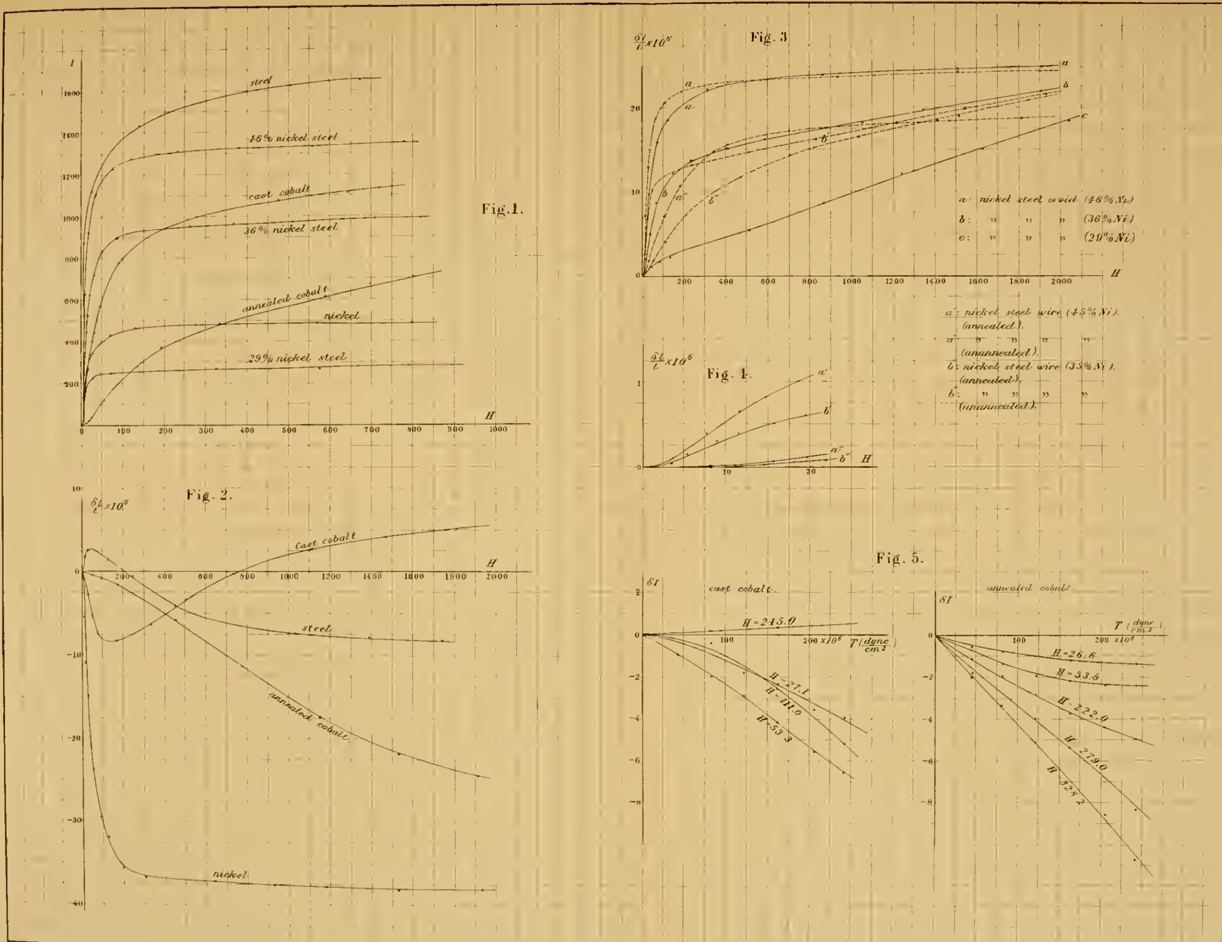


Fig. 1.
I
H
steel
46% nickel steel
cast cobalt
36% nickel steel
annealed cobalt
nickel
29% nickel steel
Fig. 2.
δl/l ×10⁶
H
cast cobalt
steel
annealed cobalt
nickel
Fig. 3
δl/l ×10⁶
H
a : nickel steel ovoid (46% Ni)
b : " " " (36% Ni)
c : " " " (29% Ni)
Fig. 4.
δl/l ×10⁶
H
a′: nickel steel wire (45% Ni).
(annealed).
a″: " " " "
(unannealed).
b′: nickel steel wire (35% Ni).
(annealed).
b″: " " " "
(unannealed).
Fig. 5.
δI
cast cobalt
H = 245.0
H = 27.1
H = 111.0
H = 53.3
T (dyne/cm²)
annealed cobalt
H = 26.6
H = 53.5
H = 222.0
H = 279.0
H = 328.2

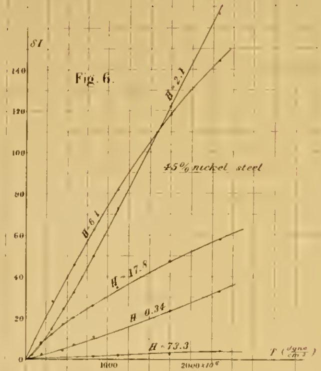


Fig. 6.

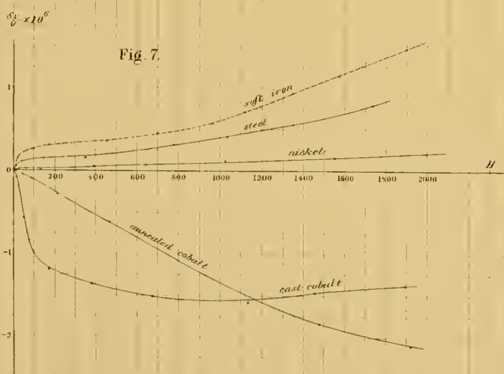


Fig. 7.

Fig. 8.

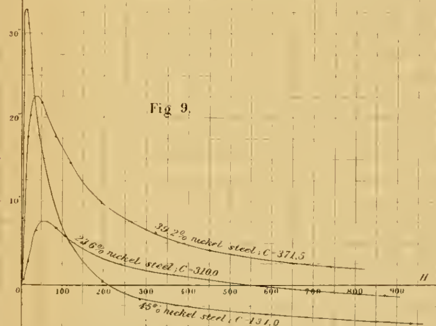


Fig 9.

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Change in Length of Ferromagnetic Wires under Constant Tension by Magnetization.

By

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and

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With Plates I—II.

1. In his earliest experiment on the change in length by magnetization of iron and steel rods, Joule[1] noticed that the effect of tension is to diminish the magnetic elongation, and that if the tension exceeds a certain limit, the magnetization causes contraction instead of elongation. Repeating the same experiment, S. Bidwell[2] made special investigations on this point. His results can be stated in the following words : Tension diminishes the magnetic elongation of iron, and causes the magnetic contraction to take place with a smaller magnetizing force ; it increases the contraction in strong fields. These changes become greater as the tension is increased. For nickel, the magnetic contraction is diminished by tension in weak fields ; but it is increased in strong fields. These changes also

1) Joule, Phil. Mag. **30**, 76, 225, 1847.

2) Bidwell, Pro. Roy. Soc. **40**, 109, 257, 1886 ; Pro. Roy. Soc. **47**, 469, 1890 ; Ewing's Magnetic Induction p. 240.

increase with tension. Cobalt is practically unaffected by tension. B. Brackett,[1] G. Klingenberg[2] and K. Tangl[3] also investigated the same subject and obtained results similar to those of Bidwell.

In Bidwell's experiment, which is generally regarded as the most reliable, the wire to be tested carried the magnetizing coil with it, so that even the smallest tension was greater than 3 kilograms per square millimeter. Hence the effect of small loading, which is remarkable in nickel, was not well studied. The reason which led him to adopt such an arrangement, was, according to his statement, to avoid the disturbance due to the electromagnetic action between the wire and the magnetizing coil. Moreover the sensibility of his apparatus could no longer be considered to be sufficiently delicate. It was, therefore, desirable to repeat his experiment with an arrangement giving higher accuracy.

A few month ago, Professor Nagaoka and one of us measured the magnetic elongation of the nickel steel, kindly placed at our disposal by Dr. Ch. Ed. Guillaume. It showed a remarkable anomaly with regard to the magnetic elongation. Much interested by the result, we proceeded to examine the effect of loading on the magnetic elongation of the alloy as well as other ferromagnetic metals.

2. The apparatus used in the present experiment is, in principle, the same as that used by Professor Nagaoka. The chief difference consists in using a rotating cylinder[4] to cause a reflecting mirror to turn through a minute angle, instead of the three pivots system.

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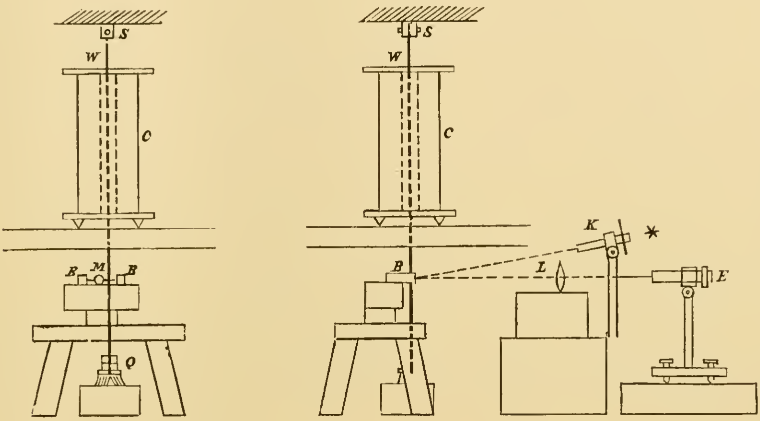
1) Brackett, Phy. Rev. [5] **5**, 257, 1897.

2) Klingenberg, Inaug.-Diss., Berlin, 1897; Beibl. **21**, 897, 1897; Inaug.-Diss., Rostock, p. 34; Beibl., **23**, 270, 1899.

3) K. Tangl, Drud. Ann. **6**, 34, 1901.

4) H. Hertz, Instrumentenkundte, **3**, 17, 1883; Gesammelte Werke. 1, p. 227.

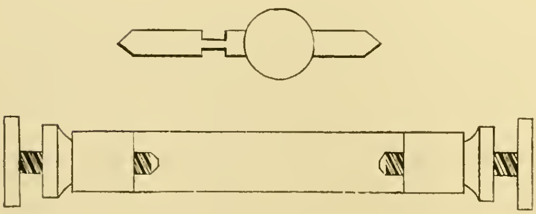
The accompanying figure shows the front and side views of the apparatus. C is the magnetizing coil, and W the wire to be tested, whose upper end is clamped to the support S, while its lower end carries a weight Q. M is a reflecting mirror fixed to the rotating cylinder, the ends of which terminate in cones and fit lightly in the agate cups on the heads of screws in brass sockets BB. K is a collimator, L a lens,and E a micrometer with ocular scale. The slit of the collimator



is illuminated by a gas flame ; the light leaves the collimator adjusted for a parallel beam and is reflected by the mirror M and converges in the micrometer field through the lens L. In the middle of the slit, a very fine glass fibre is stretched parallel to the edge, the image of which is clearly seen in the micrometer. A wire of about 1.5 mm. in diameter touches the rotating cylinder under a suitable pressure ; if the wire elongates or contracts, the mirror rotates through a small angle and the corresponding displacement of the image of the fibre is observed in the micrometer field.

The magnetizing coil was 30 cm. long and gave a field of 37.97 C.G.S. units at the centre by passing a current of one ampere. The current was measured by a Thomson graded galvanometer which

was from time to time compared with a deciampere balance. The wire to be tested was soldered into well annealed copper wires of about the same diameter, as shown in the annexed cut. It was hung vertically in the axial line of the magnetizing coil so as to lie nearly in the uniform field. The pan attached to the lower end of the wire carried on its under face a few pieces of cotton which softly touched a piece of wood for the purpose of damping without producing sensible pressure. The lens had a focal length of 66.95 cm., and the number of divisions of the micrometer ocular was 100 to 1 cm. The form of the rotating cylinder is drawn in actual size in the annexed figure. It was made of steel; the thickness of the cylinder, on which the thin vertical wire came in contact, was 2.85 and 1.51 mm. for nickel and other metals respectively. The front view of the brass socket for holding the steel cylinder is shown in the same figure. The stand on which it was fixed, could be made to move up and down as well as forward and backward by means of screw adjustment. By this arrangement, the cylinder could be made to touch the vertically suspended wire with suitable pressure, and a small rotation of the mirror be given at our disposal. The arrangement is omitted in the first figure.



The sensibility of the apparatus can easily be changed by simply altering the thickness of the rotating cylinder. In the present experiment, it was such that one division of the micrometer ocular

corresponded to an elongation or contraction of 5.13×10^{-7} in one case and 2.72×10^{-7} in the other. As $\frac{2}{10}$th of the micrometer scale can be easily observed, a dilatation of 0.6×10^{-7} per cm. was accurately measured in the latter case.

3. Observations were conducted according to the following method. The wire to be tested was hung vertically and stretched by a weight of 5 kilograms for 3 or 4 hours to make it straight. To begin with, all the weights were once taken away, and again loaded with a weight of 0.5 or 1 kilogram. After one or two hours, the observations were completed in the following order. The wire was first demagnetized, and then magnetized by passing successively increasing currents and the corresponding deflections taken, the demagnetization being repeated before each magnetization. A set of observations being thus taken, successively increasing loadings were applied and the corresponding sets of observations noted. The observations were, for the most part, taken at night to avoid small disturbing vibrations of the wire due to the shaking of the laboratory building.

Since the resistance of the magnetizing coil was only 0.6Ω, the thermal expansion of the suspended wire due to the heating of the coil was negligibly small for the current used in the present experiment; but for safety, the deflection was taken as soon as possible. Substituting for the steel cylinder a brass one of the same thickness, exactly the same results were obtained, showing that thə influence of the magnetic action between the coil and the steel cylinder is insensibly small.

When the pressure in the contact surface between the cylinder and the wire was moderate, repeated applications and removals of the magnetizing field showed no trace of slipping in the cylinder.

The wires tested had the following dimensions :—

Specimen.	Soft iron.	Wolfram steel.	Wolfram steel.	Nickel.
Length.	20.74 cm.	20.97 cm.	20.74 cm.	20.70 cm.
Diameter.	0.139	0.060	0.135	0.136

Specimen.	45% nickel steel.	45% nickel steel.	35% nickel steel.
Length.	20.73 cm.	20.93 cm.	20.75 cm.
Diameter.	0.144	0.050	0.150

4. *Soft Iron.* Fig. 1 represents the curves of the change of length in soft iron plotted against the magnetizing field; T is the tension per square millimeter. The curve T=0 is the result obtained by means of Professor Nagaoka's apparatus; our arrangement can not be used for the measurement of the change of length corresponding to no tension. The comparison of this curve with the others shows the trustworthiness of the present arrangement for measuring the minute change in length.

The specimen was very well annealed, and so the initial elongation was greatly reduced. The effect of tension is to reduce the elongation in weak fields and to increase the contraction in strong fields. This diminution of elongation becomes greater as the tension increases, till the initial elongation vanishes in a tension of about 4 kilograms per square millimeter. When the tension exceeds this value, the course of the curve is changed. In higher fields greater than 40 C.G.S. units, all the curves are nearly parallel to each other. It is also observed that the effect of tension is comparatively larger when the load is small than when it is heavy.

By making use of Fig. 1, the curves showing the relation between the change of length and the tension under a constant field are drawn in Fig. 2. We learn from these curves that the effect of tension on the magnetic change of length is not linearly related to tension.

Generally speaking, these results coincide with those of Bidwell. In our case, the reduction of the initial elongation by tension is far greater than that in Bidwell's wire. The smallest tension, by which the elongation vanishes, is about 4 times greater for the latter case than in the former. The discrepancy perhaps arises from the fact that our specimen is comparatively soft as regards the magnetic quality; this inference was actually verified in the case of wolfram steel.

Some observed changes in length under different tensions are exhibited in the following tables :—

T=167 gr.		T=827 gr.		T=2145 gr.		T=4125 gr.	
H	$\frac{\partial l}{l}\times 10^6$	H	$\frac{\partial l}{l}\times 10^6$	H	$\frac{\partial l}{l}\times 10^6$	H	$\frac{\partial l}{l}\times 10^6$
6.3	0.82	7.0	0.55	6.5	0.08	6.8	—0.08
15.9	1.89	16.3	1.13	16.3	0.22	15.7	—0.25
23.2	2.11	23.1	1.29	23.3	0.27	23.2	—0.49
40.6	1.89	34.1	1.32	38.3	0.14	36.4	—0.61
57.4	1.65	49.6	1.10	57.6	—0.22	53.7	—1.04
82.1	1.34	74.0	0.77	79.8	—0.58	74.4	—1.35
124.3	0.77	97.9	0.27	110.1	—1.13	97.5	—1.85
212.9	—0.77	156.1	—0.82	180.4	—2.61	155.2	—2.99
345.1	—2.94	277.1	—2.99	308.5	—4.71	275.4	—5.16
491.4	—4.58	430.4	—4.97	496.7	—7.14	427.0	—7.27
728.7	—5.71	728.5	—6.89	737.2	—8.43	732.0	—9.30

Here T is the tension per square millimeter, H the external field, and $\frac{\partial l}{l}$ the elongation of the wire.

5. *Wolfram Steel.* Fig. 3 represents the results for wolfram steel hardened by stretching; the anomaly of the change of length for the steel was already pointed out by Professor Nagaoka and one of us. The anomaly gradually disappears as the tension is increased; and by a tension of 25.63 kilograms per square millimeter, the steel behaves like a well annealed soft iron. The amount of the diminution of the magnetic elongation per gram is considerably smaller than that of other ferromagnetics.

Fig. 4 shows the relation between the change of length and the tension under a constant field. In this case, the proportionality between the tension and its effect on the magnetic change of length is almost satisfied.

Another wire of wolfram steel was well annealed and tested, giving the results shown in Fig. 5. Here we notice that the annealing quite effaces the anomaly, increasing at the same time, the effect of tension on the change of length.

The following table contains some of the results of observations on the hard-drawn wolfram steel:—

$T=4430$ gr.		$T=7965$ gr.		$T=15030$ gr.		$T=25630$ gr.	
H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$
36.8	0.63	34.0	0.33	34.9	0.41	34.8	0.16
46.7	1.11	45.7	0.98	43.7	0.71	50.3	0.60
68.4	2.07	67.0	1.71	62.1	1.33	75.1	0.79
89.9	2.45	88.0	2.26	82.6	1.52	99.7	0.82
138.5	2.64	137.2	2.39	125.2	1.60	158.2	0.35
256.2	2.17	252.7	1.88	209.0	1.14	278.8	—0.54
385.2	1.70	382.5	1.30	346.8	0.41	432.2	—1.36
557.8	1.36	549.0	0.87	493.2	—0.16	603.0	—1.82
740.8	1.06	733.8	0.49	733.9	—0.46	742.5	—2.23

6. *Nickel.* As will be seen from Fig. 6, the effect of tension in weak fields is to diminish the contraction due to magnetization, and the amount of diminution increases, as the tension is increased. In strong fields, the contrary is the case. Fig. 7 shows the relation between the change of length and the tension under a constant field. Each of the curves has a minimum point except in weak fields. As the field is increased, the minimum occurs by greater tension.

Some of the results of measurement are given in the following table :—

$T=863$ gr.		$T=2239$ gr.		$T=4304$ gr.		$T=5680$ gr.	
H	$\frac{\delta l}{l} \times 10^6$	H	$\frac{\delta l}{l} \times 10^6$	H	$\frac{\delta l}{l} \times 10^6$	H	$\frac{\delta l}{l} \times 10^6$
6.1	— 1.1	6.5	— 0.6	7.0	— 0.4	7.5	— 0.1
17.0	— 8.2	14.7	— 3.3	14.9	— 1.0	16.1	— 0.6
23.1	—12.1	23.5	— 7.5	23.5	— 2.8	23.4	— 1.4
30.4	—15.8	32.2	—12.0	34.3	— 5.6	32.7	— 2.6
38.6	—19.3	40.6	—16.1	49.5	—10.5	43.6	— 4.3
56.9	—24.4	56.0	—22.7	61.2	—14.8	61.4	— 8.4
81.4	—28.5	81.4	—29.1	78.9	—21.3	88.5	—16.9
122.9	—32.6	123.4	—35.0	110.1	—29.4	136.7	—28.9
208.3	—36.3	207.8	—40.1	179.3	—37.2	245.8	—38.9
306.8	—37.7	——	——	277.1	—41.8	345.1	—42.0
489.6	—38.8	——	——	382.5	—43.5	431.3	—42.8

In Bidwell's experiment, the effect of loading less than 3.5 kilograms per square millimeter was not studied ; but his general results agree with those of the present experiment.

7. *Nickel Steel.* The magnetic change of length under constant tension of the annealed nickel steel (45% Ni) whose thickness is 1.44 mm. is shown in Fig. 8. The anomaly of the magnetic elongation in nickel steel had been already observed by Professor Nagaoka and one of us. The existence of a maximum elongation, which is the characteristic for iron, is not observed, but the wire singularly elongates to an asymptotic value, as the field is increased. Apart from other ferromagnetics, the effect of tension on the magnetic elongation is considerably large ; the tension diminishes the elongation, and by a tension of 1.4 kilograms per square millimeter, the elongation is already diminished to half its value corresponding to no tension.

To study specially the effect of heavy loadings, a wire 0.50 mm. thick was made of the same alloy. After a moderate annealing, it was subjected to an experiment to see whether it would become shorter than the initial length when magnetized under a heavy loading. This actually occurred as shown in Fig. 9. With a tension of 26.9 kilograms per square millimeter, the length of the wire was decidedly shortened when magnetized. Since the degree of annealing was different in the thick from the thin wire, the magnetic change of length for these two wires in the same field and tension did not exactly coincide.

The curves showing the relation between the change of length and the tension under a constant field is shown in Fig. 10. Here we observe that the rate of the diminution of the magnetic elongation becomes less, as the tension is increased.

Some of the results of observations are given in the following table :—

$T=463$ gr.		$T=1389$ gr.		$T=2613$ gr.		$T=5070$ gr.	
H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$
6.3	2.87	5.4	2.34	6.8	1.33	6.7	0.51
15 2	6.77	15.2	5.18	15.7	3.33	16.3	1.03
23.5	9.34	34.3	8.31	23.5	4.36	33.9	1.59
46.7	13.08	43.4	9.24	46.2	5.64	49.2	1.92
68.2	14.68	61.6	10.26	67.7	6.21	67.4	2.05
89.4	15.50	81.9	10.82	88.9	6.67	88.5	2.16
138.5	16.47	125.0	11.34	137.6	6.93	136.8	2.36
256.2	17.44	213.3	12.10	252.7	7.44	251.0	2.41
385.1	17.80	350.4	12.67	381.6	7.75	381.6	2.57
636.1	18.00	658.9	13.44	625.6	8.01	627.4	2.87

With the other annealed nickel steel (35% Ni), whose thickness is 1.50 mm., the nature of the magnetic elongation and the effect of tension are generally the same as those of the former alloy, as shown in Fig. 11. The course of the curve for heavy loading is, however, quite different from that for light loading. For a tension of 4.76 kilograms per square millimeter, the wire first contracts and then elongates when the field is gradually increased, so that the form of the curve is similar to that of the magnetic change of length in cobalt. Fig. 12 shows that the rate of diminution of the magnetic elongation by tension decreases as the tension is increased.

The curves corresponding to T=0 in Figs. 8 and 11 are the results obtained by Professor Nagaoka and one of us, and are reproduced here for the sake of comparison.

The following table contains some of the results of our measurements :—

T=435 gr.		T=1299 gr.		T=2452 gr.		T=4752 gr.	
H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$	H	$\frac{\delta l}{l}\times 10^6$
5.9	1.92	7.2	1.49	6.8	0.52	6.8	+0.03
16.9	4.67	15.7	2.60	14.9	0.89	17.1	—0.06
20.3	5.60	23.2	3.29	23.5	1.12	23.3	—0.23
34.3	6.77	34.1	3.66	34.3	1.17	36.2	—0.28
66.6	7.99	68.1	4.32	73.9	1.43	73.6	—0.49
82.6	8.23	89.4	4.58	97.7	1.62	109.6	—0.52
136.8	8.59	138.1	4.89	155.9	1.75	179.3	—0.57
247.6	9.58	252.7	5.44	277.1	2.15	306.8	—0.14
375.0	9.88	378.2	5.81	427.0	2.78	503.8	+0.54
693.8	10.43	618.8	6.87	774.0	4.04	720.0	+1.14

It was our first intention to perform the same experiment on a cobalt wire in order to examine Bidwell's results; but having no such material at our disposal, we leave the subject for future considerations.

In conclusion, we wish to express our best thanks to Professor H. Nagaoka, and also to Professor A. Tanakadate for valuable advice and guidance.

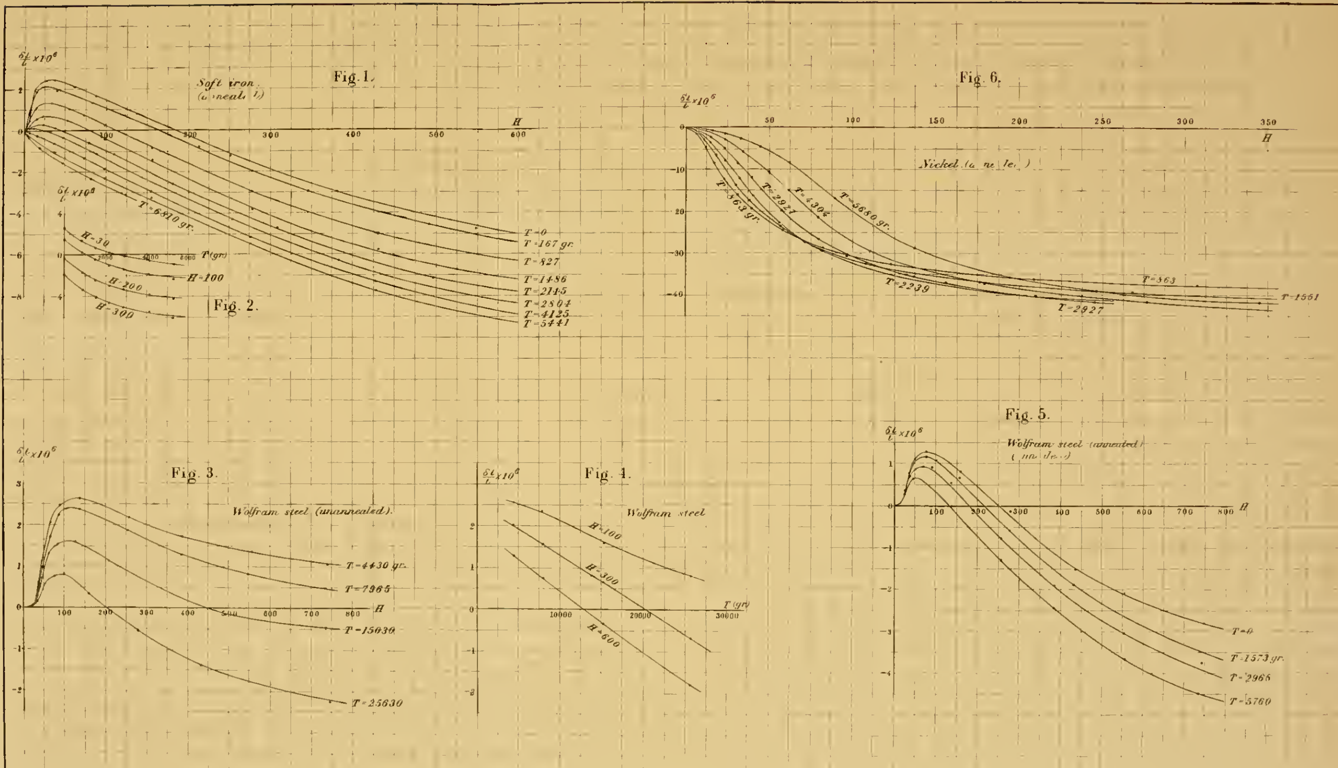


Fig. 1.
Soft iron
T=0
T=167 gr.
T=827
T=1486
T=2145
T=2804
T=4125
T=5441
T=6810 gr.
Fig. 2.
H=30
H=100
H=200
H=300
T(gr)
Fig. 6.
Nickel
T=363 gr.
T=2921
T=4304
T=5680 gr.
T=363
T=1561
T=2239
T=2927
Fig. 3.
Wolfram steel (unannealed).
T=4430 gr.
T=7365
T=15030
T=25630
Fig. 4.
Wolfram steel
H=100
H=300
H=600
T (gr)
Fig. 5.
Wolfram steel (annealed)
T=0
T=1573 gr.
T=2966
T=5760

Fig. 7. *Nickel*

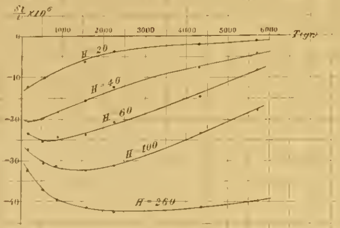


Fig. 8. *Nickel steel (45% Ni)*

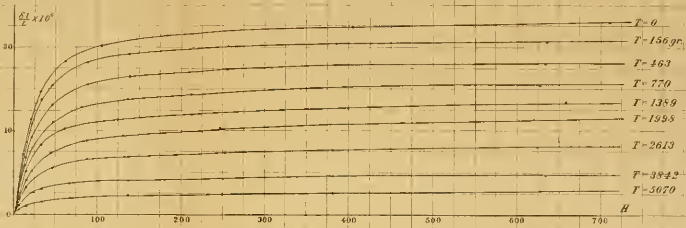


Fig 9. *Nickel steel (45% Ni)*

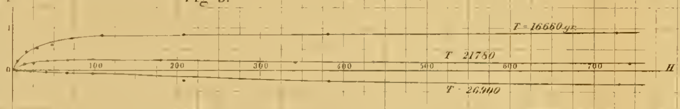


Fig. 10.

Nickel steel (45% Ni)

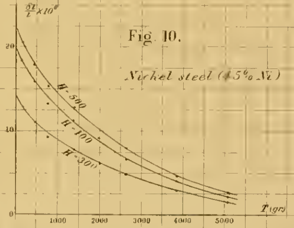


Fig. 11. *Nickel steel (35% Ni)*

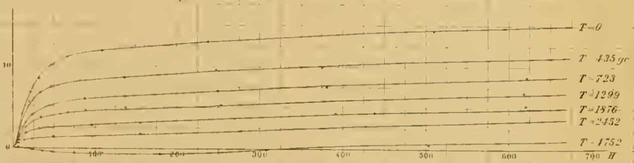
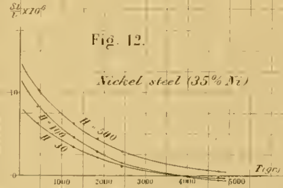


Fig. 12.

Nickel steel (35% Ni)



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Note on the Vibration of Ferromagnetic Wires placed in a Varying Magnetizing Field.

By

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and

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1. It is well known that ferromagnetic bodies emit an audible sound at the moment of making and breaking the magnetizing current. Page[1] first heard the sound in the magnet, when an electric current passed through a copper spiral placed between the poles of a horse-shoe magnet. The sound was more intense at the break than at the make. A Similar phenomenon was also observed by Delezenne[2]. Marrian[3] placed an iron or steel wire in a coil, and by making and breaking the magnetizing current, he heard a sound due to the longitudinal fundamental vibration of the wire. Matteucci[4] examined the effect of tension and found that the pitch of the sound was independent of the tension, but that the intensity was decidedly increased. The investigation with iron bars of different lengths led

1) Page, Pogg. Ann. **43**, 411, 1838 ; Wiedemann's Electricität III, 838.
2) Delezenne, Bibl. univ. ser. nouv. **16**, 406, 1838.
3) Marrian, Phil. Mag. **25**, 382, 1844.
4) Matteucci, Archives **5**, 389, 1845.

Wertheim[1] to the conclusion that each bar vibrated in its fundamental mode. By passing an intermittent current through the magnetizing coil, he heard a continuous sound, the pitch of which was the same as that of the make or break of the current. The thickness of the bar had no effect on the pitch of the sound. Nonmagnetic bodies gave no sound under similar conditions. He then concluded that the vibration of the wire was produced by the magnetic change of length. Beatson[2] noticed a sound produced in a stretched iron or steel wire carrying an intermittent current. De la Rive[3] tried, not only the bars of iron and steel, but also those of lead, zinc, bismuth, tin, antimony, platinum, gold and silver. He placed these bars between the poles of an electromagnet and passed an intermittent current through them. They all sounded, the ferromagnetic metals producing sound only with the intermittent current through them, although there was no magnetizing field acting. The experiments with fine powders of several metals and coaks gave similar result. He ascribed the phenomenon to some transpositions of molecules. Ferguson[4] and Ader[5] noticed similar phenomenon with intermittent as well as alternate currents. Trowbridge[6] found that nickel and cobalt also produced sound under similar conditions. In studying the effect of tension and compression on the intensity of sound produced in iron and nickel bars, Bachmetjew[7] found that the effect was parallel to that of the tension on the magnetic change of length. He thus concluded that the intensity of the sound is a function of the change of length by magnetization.

1) Wertheim, Pogg. Ann. **77**, 43, 1848.

2) Beatson, Electr. Mag. April 1846; Arch. de Genève **2**, 113, 1846.

3) de la Rive, Phil. Trans. **1**, 39, 1847; Pogg. Ann. **76**, 270; Arch. des Sc. phys. et nat. **25**, 311, 1866; Pogg. Ann. **128**, 452; Ann. de chim. et de phys. [4] **8**, 305, 1866.

4) Ferguson, Pro. Roy. Soc., Edinb., March 6, 1878; Beibl. **3**, 205.

5) Ader, Compt. rend. **88**, 641, 1879; Beibl. **3**, 642.

6) Trowbridge, Beibl. **3**, 289, 1879; Proc. Amer. Acad. **11**, Dec. 114, 1878.

7) Bachmetjew, Exner's Rep. **26**, 137, 1890; Beibl. 14, 537.

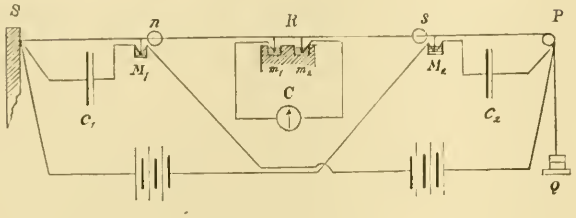
2. A short consideration of these results leads us to distinguish three kinds of the sound. The first is the combined effect of the magnetic force and the electric current. The sounds noticed by Page, Delezenne and de la Rive belong to this category ; they do not depend upon the magnetic property of the substance, but on the mechanical action produced by the magnetic force and current.

The second kind of sounds accompanies the magnetization or demagnetization of a magnetic substance at the make or break of a magnetizing current. The sounds noticed by Marrian and others belong to this category. The cause of the sound is probably the change of length by magnetization. When a magnetic substance is suddenly magnetized or demagnetized, it elongates or contracts and attains its final length, after several oscillatory changes in length have occurred in quick succession. This oscillation will produce a clinging note at the moment of magnetization or demagnetization. This view is favoured by the experiments of Marrian and Wertheim. But Matteucci found that the tension does not affect the pitch of the sound ; if his result were true, the vibration would be of more complex nature.

The third kind of sounds is one accompanying magnetization by an intermittent or alternate current of a definite frequency, or one produced when the above mentioned current is passed directly through the substance. The sound is probably produced by the continuous series of vibration above referred to. The experiments of Beatson and others will agree with this view.

De la Rive and Wiedemann ascribe the cause of the phenomenon to the molecular effect, but Wertheim and Bachmetjew to the magnetic change of length. We also consider it highly probable that the change of length is the cause producing the sound belonging to the second and third kinds. The present experiment was undertaken to get a clearer insight into the nature of the phenomenon.

3. In all previous experiments, the range of the frequency of an intermittent or alternate current was very limited ; but in our case, a string alternator[1] was introduced for continuously varying the period of the current. The arrangement is shown in the annexed figure. A copper wire is horizontally stretched ; one of the ends is fixed to a support S, while the other passing over the pulley P is attached to a weight Q. The wire is electrically insulated at the centre R, so that the current through the two mercury cups m_1 and m_2 flows in the circuit C. The battery currents pass through the two mercury contacts M_1 and M_2. The vibration of the string is maintained constantly oscillating by the electromagnet n and s. If the string is set in vibration with a single node at R, an alternate current is produced in the circuit C ; if only one set of batteries is used, an intermittent current is produced in the same circuit. The frequency of alternation or of interruption can easily be varied by the change of length and of tension of the wire. c_1 and c_2 are two condensers with a suitable capacity to diminish the sparks at the mercury contacts M_1 and M_2.



For the study of the vibration of a ferromagnetic wire under a varying field, we used Professor Nagaoka's apparatus for the measurement of the minute change of length. In the present experiment, the glass fibre in the slit of the collimator was removed and the fine slit illuminated by a gas flame was used instead. The image of the slit, after reflection by the revolving mirror and refraction through a

1) K. Honda and S. Shimizu, Amer. Jour. Sc. 10. 64, 1900; Phy. Zeitsch. 2 Jahrgang. 25. 371, 1901.

converging lens, was formed in the field of a micrometer ocular. If the wire makes a rapid longitudinal vibration, its amplitude can be measured by observing the broadening of the image of the slit.

The wire to be tested was 21 cm long and 1.50 mm thick. The magnetizing coil was 30 cm long and wound in 4 layers on a wooden frame and gave a field of 19.82 C.G.S. units due to a current of one ampere. The coefficient of self-induction of the whole circuit was 5.2×10^6 cm and its resistance 12.9 Ω, so that the time of relaxation was 4.0×10^{-4} seconds.

4. The results of experiments may be summarised as follows :—

(a) Wires of nonmagnetic metals give no sound by an intermittent or alternate field of any frequency up to 200 per second.

(b) A ferromagnetic wire emits an audible sound in an intermittent or alternate field.

(c) The pitch of the sound is always the same as that of the make or break in an intermittent or alternate current.

(d) The amplitude of vibration is in general far greater than the change in length produced by a constant field of such strength that it is equal to the maximum value of the intermittent or alternate field.

The pitch of the sound was determined by tuning a monochord to the period of the sound and counting the number of beats. From the results above mentioned, we may safely conclude that the sound produced in the ferromagnetics is due to the magnetic change in length of the wire. One make or break of the current forces the wire to accomplish a vibration, and a succession of such series constitutes a sound, the pitch of which is the same as that of the

make and break. If this view be true, the pitch of the sound due to an alternate current must be double that of the sound due to an intermittent current for the same number of vibrations of the string alternator, because the magnetic change of length is independent of the direction of the field. By an actual experiment analogous to that of Lissajous, we found this inference to be verified. The above results also show that the magnetic change of length occurs so quickly as to follow rapid changes of magnetization of as much as 150 reversals per second.

If the frequency be kept constant, the relation between the amplitude of vibration and the maximum field during one complete period of vibration is similar to the relation of the change of length to a steady field. The maximum field used in most of our experiments was 30.7 C.G.S. units.

It is also to be observed that if an intermittent or alternate current is passed through a spiral of nonmagnetic metal, an audible sound is produced. This is perhaps due to the periodic attraction of the currents flowing through the spiral in the same direction, and is of a quite different nature from the sound above referred to.

5. Gradually varying the frequency of the intermittent or alternate current, while the range of the field was kept constant, we observed the singular phenomenon that the amplitude of vibration passed through several maxima and minima. Two marked maxima and minima were observed in the case of nickel wire. The maxima occurred at the frequencies of 80 and 150 per second, while the minima at the frequencies of 68 and 140 per second. The phenomenon which was chiefly due to the longitudinal vibration of the wire, was, to a certain extent, modified by the resonance of the system, consisting of a reflecting mirror and two springs attached to it,

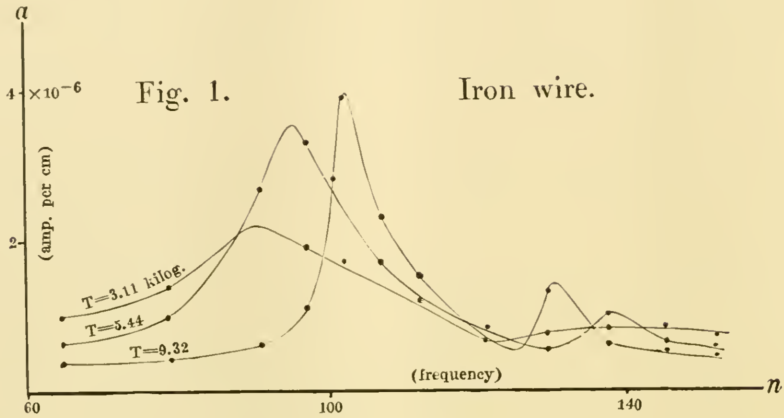
to the periodic vibration of the wire due to the magnetic change of length. The positions of the maxima and minima were not, however, materially changed by the length of the wire, or the tension of the springs. In the case of iron, the magnetic change of length for the same field strength was small, so that the phenomenon was not very marked.

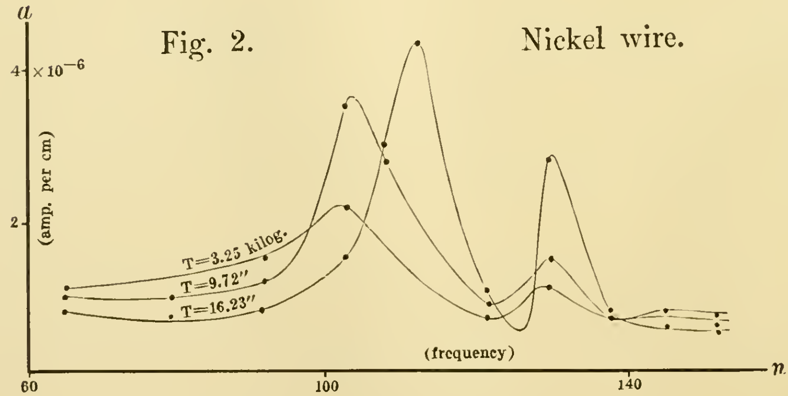
To study the phenomenon specially, we used another arrangement; the apparatus was the same as that described in the preceding paper, used for the measurement of the magnetic change of length under constant tension. The wire to be tested was about 60 cm long and 0.4 mm thick; to the extremities of the wire, two copper wires of nearly the same thickness were soldered. It was hung vertically in the axial line of a magnetizing coil 80 cm long so as to lie nearly in a uniform field, and to its lower end was attached a weight. Near the lower end of the copper wire, a thin rotating cylinder carrying a reflecting mirror was placed horizontally and came in contact with a suitable pressure to the vertical wire. The working of the arrangement was the same as in the preceding experiment.

The magnetizing coil was wound in 4 layers and gave a field of 26.0 C.G.S. units due to a current of one ampere. The coefficient of self-induction of the whole circuit was 1.66×10^7 cm and its resistance 18.2 Ω, so that the time of relaxation was 9.1×10^{-4} seconds.

With the above arrangement, we found also two marked maxima in the amplitude of vibration for iron as well as for nickel. The amplitude of vibration is plotted against the frequency of the current in Figs. 1 and 2. In both cases, the maximum field during one complete period of vibration is 28.5 C.G.S. units, and the weight

attached to the lower end of the wire is reduced to the weight per square millimeter.





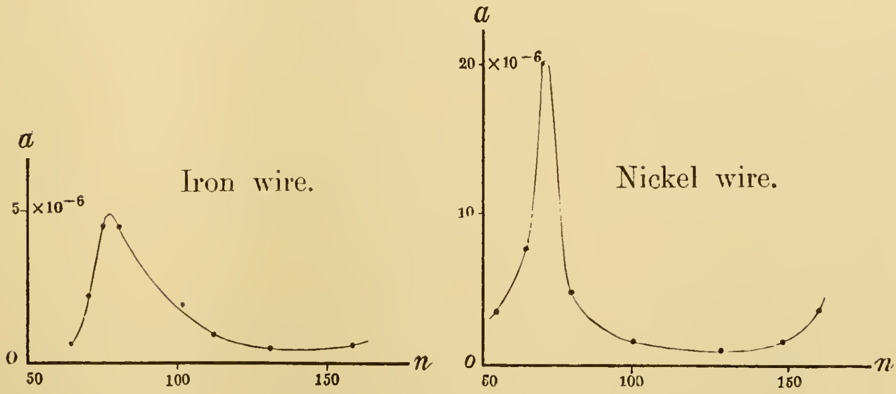
As will be seen from the figures, the maximum amplitude of vibration and the frequency corresponding to the maximum increase with weight. By altering the length of the ferromagnetic wire, the positions of the maxima and minima are but slightly affected.

These positions of the maxima and minima do not coincide with those in the former case; the first maximum occurs in a higher

frequency and the second in a lower one, the difference amounting in each case to about 20. The first maximum is also of a frequency higher by at least 2.5 times than that calculated on the consideration that the phenomenon is due simply to the elastic vibration of the wire.

Instead of attaching a weight to the free end of the wire, the same end was stretched by means of a spiral spring fixed to the stand. Varying the frequency of the intermittent or alternate current, the maxima and minima of the amplitude of vibration were also observed, as shown in Fig. 3. In this case, the first maximum occurred at a frequency of about 75 per second for iron as well as for nickel, and the second at a frequency higher than 160 per second for these two metals. These positions of maxima and minima were almost independent of the tension and of the length of the spring.

Fig. 3.



Whether these complicated phenomena are capable of being explained simply by the elastic vibration and the magnetic change of length without taking account of the time-lag, or whether they prove the existence of this effect, requires further experimental and theoretical considerations.

Our best thanks are due to Professor Nagaoka and also to Professor Tanakadate for their kind guidance in carrying out the present experiment.

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Absolute Messung der Schwerkraft in Kyōto, Kanazawa, Tōkyō und Mizusawa mit Reversionspendeln ausgeführt

von

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Mit 2 Tafeln.

Aeltere Messungen.

Die erste Bestimmung der Schwerkraft in Tōkyō wurde von Ayrton und Perry 1878 unternommen. Ein Drahtpendel, welches 9,3*m.* lang war, wurde mit einer Stahlschneide versehen und an einem Balken im Hauptgebäude des Polytechnischen Instituts (des damaligen Kōbudaigaku) in Tōkyō aufgehängt, und mit der Amplitude von 30*cm.* am unteren Ende in Schwingung versetzt. Die Schwingungsdauer dieses Pendels wurde mit dem Chronograph

durch Quecksilberunterbrechung bestimmt. Mangelhaft wie diese Methode der Zeitbestimmung erscheinen mag, war die Längenbestimmung dieses Pendels noch gröber, als der Draht bei der Abmessung horizontal auf zwei Flaschenzüge gestreckt wurde. Keine Correction für die Krümmung der Schneide und für die Mitschwingung wurde angebracht; überdies ist die Temperatur des Drahtes nicht genau ermittelt worden. Als schliessliches Resultat dieser rohen Schweremessung ergab sich der Wert für

$$g=979{,}82\frac{cm.}{sec.^2}$$

für die Breite 35° 40,′1 und die Länge östlich von Greenwich 138° 44′,8.

Eine feinere Messung wurde einige Jahre später von Mendenhall mit dem Borda'schen Pendel ausgeführt. Das Pendel wurde von Salleron nach dem Apparat von Borda construirt. Am Ende eines feinen Platindrahtes, ungefähr ein Meter lang, wurde eine Messingkugel von 36*mm.* Durchmesser angelöthet. Die Schwingungsdauer wurde mittelst eines Chronographs, welcher mit einem Chronometer in Verbindung stand, gemessen. Die Längenmessung geschah durch eine Scala, die von demselben Mechaniker geliefert und mit einem metallischen Thermometer versehen wurde. Unter den verschiedenen Korrectionen, die zur Reduction der Beobachtung vorgenommen werden müssen, fehlten diejenige für die Krümmung der Schneide sowie für die Mitschwingung, welche letztere, wie man leicht aus dem kleinen Momente der schwingenden Kugel ersehen wird, ziemlich gering gewesen sein muss. Als schliessliches Resultat fand er

$$g=979{,}84\frac{cm.}{sec.^2}$$

für die Breite 35° 41′,4 und die Länge 139° 46′,6.

Im Jahre 1883 haben die Herren Smith und Pritchett des U. S. Coast und Geodetic Survey, Tōkyō an Washington, Singapore und San Francisco angeschlossen, mittelst drei invariablen Pendeln, die auch von Herschel und anderen zur Anschlussmessung zwischen Greenwich, London, Washington und anderen Orten, gebraucht worden sind.

Der Unterschied in der Schwingungsdauer des Pendels No. 4 ist ziemlich gross im Vergleich mit den zwei anderen. Walker schreibt dieses einem fremden Körper zu, welcher ohne sein Wissen mit dem Pendel die Bewegung mitgemacht haben möge. Nach unserer Erfahrung finden wir oft grosse Schwankungen der Schwingungsdauer, während der langsam verlaufenden Erdbeben. Solche Bewegung entgeht unserer Empfindung, aber mit dem Horizontalpendel kann man die Bodenschwankung messen. Da ein solches Instrument während dieser Messung nicht aufgestellt worden war, so ist es nicht mit Gewissheit zu sagen ob die Hauptursache dem Erdbeben zuzuschreiben sei ; aber es ist höchst wahrscheinlich dass in Tōkyō, wo man sehr oft Bodenschwankungen der oben geschriebenen Art verspürt, das Pendel auch von einem solchen Ereigniss betroffen wurde (siehe w. u.)

Wegen dieser Abweichung findet man keine Uebereinstimmung der Resultate unter einander ; als Mittel dieser drei Messungen findet man

$$g = 979{,}824 \frac{cm}{sec^2}$$

mit Anschluss an den von Defforges für Greenwich gefundenen Wert. Es ist aber zu bemerken dass der Unterschied zwischen den zwei Pendeln No. 4 und No. 11 gleich $0{,}2 cm/sec^2$ ist ; ferner fehlt für jede Station die Korrection für die Mitschwingung, was dem Wert der Resultate viel einträgt.

Lieutenant Muttoné der Kaiserlichen Österreich-ungarischen Marine hat im Jahre 1896 die Schwerkraft in Tōkyō (auf der Sternwarte) an diejenige in Pola angeschlossen. Dabei wurde das Halbsecundenpendel nach Sterneck gebraucht. Die so erhaltenen Beobachtungen der Koincidenzen stimmen ziemlich gut zu einander, aber der Wert der Schwerkraft ist ausserordentlich klein gegen die drei anderen Messungen, die wir oben kurz skizzirt haben. Hierbei wurden alle Korrectionen mit Ausnahme der Mitschwingung berücksichtigt und die Aenderung, die das Pendel während der Reise erlitten haben mag, ist äusserst klein, wie die Beobachtungen vor und nach der Reise klar machen werden. Trotz dieser schönen Uebereinstimmung und der scheinbaren Unveränderlichkeit des Pendels findet man abnorme Werte der Beschleunigung der Schwerkraft. Für Tōkyō (Breite 35° 39′,3) giebt Muttoné

$$g = 979{,}687 \frac{cm}{sec^2}$$

während er für Yokohama, welches einige Minuten südlich von Tōkyō liegt, findet

$$g = 979{,}745 \frac{cm}{sec^2}$$

Die hier angegebenen Zahlen zeigen grosse Schwerestörung in der Nähe von Tōkyō. Es ist hiernach selbstverständlich dass irgend welcher Fehler in den beiden Resultaten versteckt liegt.

Wie bereits von Herschel bemerkt worden ist, leidet die Beobachtungungsmethode von Ayrton und Perry an grosse Unsicherheit ; obgleich das Resultat von Smith und Pritchett dem Wert des anderen Beobachters nahe kommt, so sind die einzelnen Beobachtungen stark von einander abweichend, sodass man kein grosses Gewicht darauf legen kann. Nur die Messung von Mendenhall ist etwas zuverlässiger ; hätte er ein Instrument von noch neuerer Konstruction gebraucht, so würde es fast unnötig gewesen sein das

Experiment zu wiederholen. Gegenwärtig kann man den Genauigkeitsgrad bedeutend steigern, wenn man mit einem geeigneten Messapparat die Beobachtungen ausführt und die verschiedenen Korrectionen, die früher gar nicht berücksichtigt worden sind, in Betracht zieht.

Aus den oben angegebenen Resultate ersieht man dass die Schwerkraft in Tōkyō, mit Ausnahme der Muttoné'schen Messung, viel grösser ist als die für gleiche Breite an anderen Orten gefundenen Werte. Als Regel aber findet man Abweichungen in demselben Sinne für die meisten Inselstationen.

In Ermangelung einer genauen Messung war es sehr wünschenswert die Beobachtung mit einem anderen feineren Instrumente zu wiederholen und die Frage aufzuklären, ob ein bedeutender Unterschied zwischen dem berechneten und dem beobachteten Wert wirklich bestehe. Nicht nur von der geodätischen und der physikalischen Seite schien es höchst interessant für die Erdbebenforschung die Dicke der störenden Schicht auszurechnen, da diese Schicht offenbar mit der Häufigkeit der Erdbeben in unserem Land eng verknüpft sein wird. Bei der Begründung der Erdbebenuntersuchungskommission, sind zwei von uns (N. und S.) mit der Messung der Schwerkraft beauftragt worden; nachher ist diese Abteilung der japanischen geodätischen Kommission eincorporirt worden, sodass die hier zu beschreibenden Resultate die Vorarbeiten zur absoluten Schweremessung an vier Stationen darstellen. Andererseits wurde die Schweremessung des Landes nach der Methode der relativen Messung mit dem Halbsekundenpendel unternommen, sodass die Wahl mehrerer Stationen zur absoluten Messung nicht nötig ist. Deswegen schien es uns wünschenswert diese Messungen zuerst zu veröffentlichen, da es gegenwärtig nicht in Aussicht steht die absoluten Messungen an anderen Orte auszuführen.

Der Apparat.

Der Pendelapparat, den wir zur Bestimmung der Beschleunigung der Schwerkraft gebraucht haben, stimmt im wesentlichen mit dem neueren des Königlichen Geodätischen Instituts zu Potsdam überein. Der auf Anregung des Herrn Geheimrat Helmert von Repsold und Söhne construirte Apparat besteht aus zwei Pendeln von gleichem Gewichte, aber mit verschiedenen Schwingungsdauern. Die genannte Firma unternahm im Jahr 1893 die Konstruction desselben Apparates, welcher in den wesentlichen Punkten mit demjenigen des geodätischen Instituts fast gleich ist, mit Ausnahme des Pendelkastens und der Vacuumvorrichtung. Er wurde schon 1894 fertig gestellt, aber infolge verschiedener Hindernisse konnten die Beobachtungen erst im Sommer 1897 begonnen werden. Die hier mitgeteilten Resultate beziehen sich auf die Messungen, die 1899 und 1900 von uns ausgeführt worden sind.

Die beiden Pendel wiegen 3,63*kg* und die Schneidenabstände betragen 1*m*. und 0,25*m*. resp., sodass eins als Sekunden-und das andere als Halbsekunden-pendel diente. Die Achatschneiden sind in Messinghülsen durch zwei Druckschrauben festgeklemmt ; sie sind aber vertauschbar und können für Sekunden-und Halbsekunden-pendel gebraucht werden. Die Kanten der Schneiden bilden einen Winkel von 120° für eine Breite der einigen Micron, dann wurde der Kantenwinkel auf 90° verringert.

Beim Meterpendel wurde die Stange zu schwach und stark biegsam gefunden. Sie besteht aus einem gezogenen Messingcylinder von 15,9*mm* Durchmesser, dessen Enden etwas kegelförmig gedreht worden sind. Diese endigen in Hülsen, mittels welcher das Pendel auf die Konsole gelegt werden kann. Über diese Unterbrechung, hinaus setzten sich die Kegel weiter fort, bis sie in zwei Cylindern endigten. Der schwere Cylinder ist aus gegossenem Messing und ist

32,8*mm.* hoch bei 79,8*mm.* Durchmesser, während der leichte Cylinder aus Messingblech angefertigt ist und ganz dieselbe äussere Gestalt hat wie der Schwere. Dieser Cylinderkasten wurde durch eine Messingstange längs der Axe versteift; um einen Druckunterschied innerhalb der Kastens zu vermeiden, wurde er mit einer kleinen Schraube specieller Construction versehen, welche die innere Luft mit der äusseren in Verbindung setzt. Die beiden Cylinder, mit den dazu gehörenden kegelförmigen Stangen, wurden an das Pendel festgeschraubt, sodass man diese untereinander vertauschen konnte. Neben der Achatschneide findet man an beiden Seiten einen kleinen ebenen Spiegel zur Beobachtung der Schwingungsdauer durch Konicidenzapparat.

Das Halbsekundenpendel ist viel steifer als das Sekundenpendel aber ähnlich gebaut. Da das Gewicht dieses Pendels mit dem Meterpendel gleich sein muss, so wurde die Mitte der Stange durch einen dicken Cylinder verstärkt. Die beiden Cylinder an den Enden der Stange wurden vertauschbar gemacht wie bei dem Meterpendel.

Das Stativ ist aus massivem Gusseisen und kann an der Wand oder an einem Pfeiler festgeschraubt werden. An einem hervorragenden Teil des Stativs, nicht weit vom Pfeiler wurde eine Achatebene auf der Konsole festgelegt. Durch drei starke Schrauben, welche in das Stativ eingelegt sind, kann man die Achatebene nivelliren. Wenn das Pendel auf die Konsole gelegt wurde, so konnte man mittelst einer Schraube, die ausserhalb des Stativs gedreht werden kann, das Pendel auf der Ebene legen oder von dieser wegschieben, ohne es mit der Hand zu berühren.

Das Pendel war von einem grossen Hohlcylinder aus Messingblech umgeben, welcher mittelst mehreren Schrauben an dem Stativ festgehalten wurde. Über das Stativ wurde eine Glasglocke gedeckt, sodass sie mit dem einen Teil der Stativs und dem Cylinder einen

Luftdichtkasten bildet. Damit man das Pendel unter verschiedenem Druck schwingen zu lassen konnte, wurde der Cylinder mit einem Manometer versehen, und mit einem Ventil, wodurch man die Luft aus dem Pendelkasten pumpen konnte. Dieser Metallkasten bildet eine Isothermfläche, um die Temperatur innerhalb constant zu halten.

Zur Bestimmung der Pendeltemperatur dienten zwei Thermometer, die in $\frac{1}{10}$ Grad geteilt sind; die Quecksilberkugel des oberen Thermometers wurde in der Nähe der Schneide angebracht und die des unteren nahe der Mitte der Pendelstange.

Der Schneidenabstand wurde mittelst Vertikalcomparators gemessen, welcher an das Stativ geklemmt werden kann. Die Microscope wurden mit Fadenmicrometer versehen, dessen Bewegung an der Trommel, welche in 100 Teile geteilt war, abgelesen werden konnte. Einem Teilstrich entspricht ungefähr ein Micron. Der Maassstab hat H-förmigen Querschnitt und war aus Phosphorbronce. Die Correction sowie der Ausdehnungscoefficient des Stabes wurde im Bureau international des poids et mesures in Sèvres bestimmt. Die Scala wurde, während der Beobachtung, gegen die Wärmestrahlung durch eine besondere Vorrichtung geschützt.

Biegungscorrection.

Wie von Helmert in seiner Theorie des Reversionspendels genau discutirt wurde, bietet die Biegungscorrection des Meterpendels die Hauptschwierigkeit bei der Bestimmung des Schwerkraft, wenn man sich eines biegsamen Pendels bedienen will. Zur genauen Bestimmung dieser Korrection benötigt man der Kenntniss der Dichtigkeit und des Dehnungsmoduls der Pendelstange, sowie deren geometrischer Gestalt.

Zu diesem Zwecke wurde ein kleines Stück des Messingstabes, aus welchem die Pendelstange angefertigt ist, von Repsold bezogen

und die Dichtigkeit desselben durch hydrostatische Wägung bestimmt. Es ergab sich durch dieses directe Verfahren die Dichtigkeit der Stange zu 8,571. Da aber das Pendelgewicht nicht aus gezogenem sondern aus gegossenem Messing gemacht ist, so war, wie gewöhnlich, ein Dichtigkeitsunterschied zwischen diesen zwei Arten von Messing anzunehmen. Leider konnten wir das Gewicht nicht ins Wasser eintauchen, daher haben wir es zweckmässig gefunden das Gewicht herauszuschrauben und dessen Gewicht sowie das Volumen zu bestimmen, um daraus die Dichtigkeit genau ausrechnen zu können. Es ergab sich dabei für die Dichtigkeit der Wert 8,203, welcher bedeutend kleiner ist als für die Pendelstange. Dieser Unterschied wurde in der Rechnung der Biegungscorrection berücksichtigt, da der Einfluss des schweren Gewichtes auf die Biegungscorrection beträchtlich ist.

Um die Rechnung der Biegungscorrection einigermassen erleichtern und gleichzeitig controlliren zu können, wurde die Integration teils mechanisch, teils direct ausgeführt. In demjenigen Teil der Pendelstange, wo der Durchmesser constant bleibt, wurde auf 480*mm*. Länge, das Integral

$$\frac{d^2\eta_0}{da^2} = \frac{g}{E\mathfrak{T}}\left\{ \int_a^{1156.8} (x-a)\,dv' - \frac{1}{l}\int_a^{1156.8} \mu\mathfrak{T}'dx \right\}$$

direct berechnet ; im übrigen Teile wurde die Methode der mechanischen Quadratur verfolgt, da man leicht den Rechnungsfehler constatiren, und schon durch gleiche Teilung in je 10*mm*. die Integration ziemlich genau vornehmen kann. Zu dem Zwecke wurden die Pendelgewichte und die Stange in Intervallen von 10*mm*. mit dem Kontactmicrometer, wodurch ein Dickenunterschied von 0,01*mm*. sich leicht constatiren lässt, gemessen. Wo man das Volumen oder den Trägheitsradius nicht durch directe Messung finden konnte, wurden diese Werte durch ein besonderes Verfahren bestimmt.

Der Dichtigkeitsunterschied für das schwere Gewicht, welches wie oben bemerkt wurde, kleiner ausfiel wie diejenige der Stange, wurde das Integral mit einer Konstante multiplicirt, damit alle Teile auf die gleiche Dichtigkeit (*d. h.* 8.571) reducirt werden könnten. Gleiches gilt auch für die Achatschneide, aber der Einfluss dieses Teils auf die Biegungscorrection ist äusserst gering.

Nicht minder wichtig als die Dichtigkeitsdifferenz ist die Rolle, welche die Elasticitätsconstante in dieser Correction spielte. Da der biegsamste Teil des Pendels eine ungefähr ein Meter lange Stange bildet, so wurde die Elasticitätsconstante dieses Teils mit grosser Sorgfalt untersucht. Es ist immer zu befürchten, dass man einen zu kleinen Wert erhielte, wenn man zu dieser Untersuchung das Microscop benutzen würde, da die Stützpunkte gewöhnlich niedergedrückt und dadurch die Biegung scheinbar grösser gefunden wird. Diese Unsicherheit zu vermeiden, haben wir den cylindrischen Teil der Stange auf zwei Stützen gebracht und zwei kleine Spiegelchen an beiden Enden, da wo die Stange kegelförmig zu werden anfängt, vertikal befestigt durch eine besondere Vorrichtung, welche die Stange keineswegs beschädigt. In der Mitte dieses Cylinders, wurde ein, einige hundert Grammes schweres Gewicht aufgehängt, und mittels Scala und Fernrohr konnte man die Verschiebung der Scalenteilung sehr genau an den durch die zwei Spiegel reflectirten Bilder messen und die Senkung daraus berechnen. Als Resultate mehreren Beobachtungen fanden wir

$$E = 9{,}491 \times 10^{11} \quad \textit{C.G.S. Einheiten.}$$

Hieraus ersieht man dass die Elasticitätsconstante unseres Pendels kleiner als beim Potsdamer Pendel ist; trotz dieses Unterschieds fällt dort die Biegung viel grösser aus als mit dem unseren, was durch die Differenz der Dichtigkeit und der geometrischen Gestalt des Pendels bedingt wird.

Die Rechnungsresultate sind in folgender Tabelle gegeben; dabei sind Helmert's Bezeichnungen gebraucht

	Schweres Gewicht unten.	Schweres Gewicht oben.
$\Sigma\eta_0 dv'$	$+\ 18858$	$+\ 75510$
$\frac{1}{l}\Sigma\mathfrak{T}'\beta_0 dx$	$-\ 168$	$-\ 225$
$i_1-i_2-i_3$	$+163070$	$+649120$

Benutzt man diese Werte, so erhält man als Biegungscorrection für die Länge des Sekundenpendels

$$-329\mu^*$$

Die Dichtigkietsbestimmung scheint die Hauptursache der Unsicherheit in dieser Bestimmung zu sein; es ist wohl möglich dass dieser Wert von der Wirklichkeit um einige Procent entfernt ist. Ausserdem ist die Aenderung der Elasticität an denjenigen Stellen, wo die Endgewichte dem Pendel angeschraubt sind, nicht berücksichtigt; es mag, nach genauerer Untersuchung, noch eine Korrection hinzuzufügen sein, die den oben hergeleiteten Wert um einen geringen Bruchteil modificiren wird.

Bestimmung der Schwingungsdauer.

Zur Bestimmung der Schwingungsdauer haben wir immer das Chronometer Negus 1891 gebraucht. Zweifellos erzielt man genauere Resultate mit der Pendeluhr, aber die Häufigkeit der Erdbeben in unserem Inselreich verbietet uns den Gebrauch der sonst schöngehenden astronomischen Pendeluhr. Das Erdbeben, welches als starker Stoss unserem Körper fühlbar ist, macht das Pendel sehr unregel-

* Im Berichte der 13ten Konferenz der internationalen Erdmessung wurden die Resultate, wobei die Biegungscorrection $=320\mu$ angenommen ist, mitgeteilt. Die Rechnung wurde revidirt und für einen Fehler corrigirt.

mässig schwingen, so dass nicht nur die Schwingungsbeobachtung selbst, sonderen auch die der zur Bestimmung der Schwingungsdauer dienenden Uhr durch solchen Stoss gestört wird, und oft erfolgt zuletzt ein ganz unregelmässiger Uhrgang. Es ist in der That eine unglückliche Eigenschaft des Landes, dass man die anderswo sehr genau gehende Pendeluhr zum Zwecke der astronomischen Beobachtung und der Schwerkraftsbestimmung nicht benutzen kann. Man hat demnach von dieser Uhr abzusehen, und das Schiffschronometer an deren Stelle zu setzen. Dass das Instrument gegen kleine Störungen wie schwaches Erdbeben sich sehr gut verhielt, macht es schon für unseren Zweck ganz empfehlenswert, aber es hat verschiedene Nachteile, die man nicht leicht vermeiden kann. Der tägliche Gang des Chronometers ist nicht so regelmässig wie bei der Pendeluhr; es entstehen bisweilen Unregelmässigkeiten beim Aufziehen. Die Kompensation des Chronometers kann nicht so genau geschehen wie bei der Pendeluhr, sodass die Störung durch Aenderung der Temperatur und des Luftdruckes nicht zu vermeiden ist; gegen die Wirkung der ersteren muss man besondere Sorgfalt nehmen damit das Chronometer regelmässig geht. Ausserdem ist das Instrument bisweilen plötzlichen Aenderungen unterworfen, sodass man sich nicht ganz sicher auf die Beobachtung verlassen kann, die nur mit einem Chronometer ausgeführt wurde. Man nimmt daher mindestens zwei Chronometer mit, die oft unter einander verglichen und in Bezug auf plötzliche Aenderungen controllirt und corrigirt werden müssen.

Zur Bestimmung des täglichen Gangs haben wir immer die Zeitbestimmung mit dem Durchgangsinstrument ausgeführt; gewöhnlich wurden 7 oder 8 Sterne jede Nacht beobachtet und der Durchgangsmoment an 5 Fäden, mit welchen das Instrument versehen war, chronographisch registrirt. Der mittlere Fehler der durch die Methode der kleinsten Quadrate reducirten Zeitgleichung beträgt

ungefähr $\pm$ 0,02 *sek.* Wie man aus der Tabelle des täglichen Gangs leicht ersieht, ist er nicht constant; wo die Beobachtung wegen der schlechten Witterung unterbrochen werden musste, wurde der mittlere Wert eingesetzt.

Die Schwingungsdauer wurde durch die Koincidenz des Pendels mit dem Chronometer gefunden. Zur Beobachtung der Koincidenz wurde ein Apparat construirt, welcher im wesentlichen mit dem Sterneck'schen übereinstimmt. Da aber das Koincidenzintervall beim Sekundenpendel mehr als $2\frac{1}{2}$ Minuten betrug, so war es nötig die Vergrösserung des Fernrohrs zu steigern, und das Ocular mit einem Micrometer, welches in $\frac{1}{10}$*mm.* geteilt war, zu versehen. Die Genauigkeit der Decimalschätzung wurde durch das Micrometer erheblich gesteigert. Wegen der Vergrösserung des Fernrohrs war es nötig den Spalt mit einer kleinen elektrischen Lampe zu beleuchten. Dieser Apparat wurde mehr als $2\frac{1}{2}$*m.* weit vom Pendel auf dem Steinpfeiler aufgestellt. Vor der Koincidenzbeobachtung wurde das Pendel, welches durch eine Hinterschraube von der Achatebene frei gehalten ist, auf der Konsole niedergelassen und durch einen leichten Hebel, der sich von Aussen bewegen lässt, in Schwingung versetzt. Man konnte durch die Lage des Hebels dem Pendel schon eine passende Amplitude erteilen, um stets mit demselben Schwingungsbogen die Periode zu beobachten. Die Temperaturen wurden mittels zweier Thermometer angegeben. Die Quecksilberkugel des oberen Thermometers stand einige Centimeter von der Pendelschneide, während sich die des unteren in der Mitte des Kastens befand. Bei dem Sekundenpendel kam das letztere in demselben Niveau wie die Mitte der Pendelstange zu stehen und beim Halbsekundenpendel stand es ungefähr 20*cm.* unter dem Endgewichte. Man fand gewöhnlich dass das obere Thermometer eine höhere Temperatur zeigte als das untere, wie es leicht das Vorhandensein des Temperatur-

gradients an das Licht bringt. Die Temperatur des Pendels wurde nach folgendem Schema berechnet.

$$\text{Temperatur des Sekundenpendels} = \frac{[\text{Oben}] + 3[\text{Unten}]}{4}$$

$$\text{Temperatur des Halbsekundenpendels} = \frac{4[\text{Oben}] + [\text{Unten}]}{5}$$

Diese Thermometer wurden von Zeit zu Zeit mit den Normalthermometern No. 4242 und No. 4243 verglichen, welches wieder in der Physikalisch-Technischen Reichsanstalt zu Charlottenburg untersucht worden waren.

Der Dunstdruck wurde mit dem August's Pschychrometer gemessen, das nahe dem Pendelkasten aufgehängt war. Der Luftdruck wurde mit dem Quecksilberbarometer in Kyōto beobachtet; anderswo wurde ein Aneroid (Casella No. 2452), das mit dem Normalbarometer verglichen war, gebraucht.

Durch die Vergleichung mehrerer Messungen der Schneidenabstände des Sekundenpendels bei verschiedener Temperatur findet man für den mittleren Ausdehnungscoefficienten der Pendelstange zwischen 20° und 30° den Wert

$$0{,}00001855.$$

Bei einer Temperaturdifferenz um 1°C beträgt die Korrection der Schwingungsdauer für das Sekundenpendel

$$93 \times 10^{-7} sec.$$

und für das Halbsekundenpendel

$$46 \times 10^{-7} sec.$$

Der Einfluss der Luftdruckschwankungen auf die Schwingungsdauer eines Reversionspendels ist äusserst gering; schwingt man aber das Pendel in anderer Lage bei anderem Druck, so hat man bisweilen einen Korrection für den Unterschied der verdrängten Luft hineinzubringen, die sich folgendermassen berechnen lässt.

Folgt man den Bezeichnungen von Helmert und setzt die Masse der verdrängten Luft gleich m und $m+\partial m$, wenn die Schwingungsdauer resp. gleich T_1 und T_2 ist, so wird

$$T_1^2 L\,(Mh_1 - mh_l) = M\,(k^2+h^2)+\gamma m$$

$$T_2^2 L\,\{Mh_2-(m+\partial m)h_l\} = M\,(k^2+h^2)+\gamma\,(m+\partial m)$$

Durch Subtraction erhält man

$$L\left\{T_1^2h_1-T_2^2h_2-\frac{mh_l}{M}(T_1^2-T_2^2)+\frac{\partial m}{M}h_lT_2^2\right\}=(h_1-h_2)\,\Lambda-\gamma\frac{\partial m}{M}$$

Setzt man

$$\frac{T_1^2h_1-T_2^2h_2}{h_1-h_2}=\tau^2$$

so wird

$$L=\frac{\Lambda}{\tau^2-\frac{h_l(T_1^2-T_2^2)}{h_1-h_2}\;\frac{m}{M}+\varepsilon}$$

wo

$$\varepsilon=\frac{\partial m}{M(h_1-h_2)}\left(h_lT_2^2-\frac{\gamma}{L}\right)$$

Da

$$\tau \doteq T_1+\frac{h_2(T_1-T_2)}{h_1-h_2}$$

so wird

$$L=\frac{\Lambda}{\tau^2}\left(1+h_l\frac{(T_1^2-T_2^2)}{\tau^2(h_1-h_2)}\;\frac{m}{M}-\frac{\varepsilon}{\tau^2}\right)$$

Vernachlässigt man γ, welches eine sehr kleine Grösse ist, so wird

$$\varepsilon \doteq \frac{\partial m}{M}\;\frac{h_l}{h_1-h_2}\tau^2$$

Man erhält dadurch

$$L=\frac{\Lambda}{\tau^2}\left(1+\frac{h_l(T_1^2-T_2^2)}{\tau^2(h_1-h_2)}\;\frac{m}{M}-\frac{\partial m}{M}\;\frac{h_l}{h_1-h_2}\right)$$

$$=\frac{\Lambda}{\tau^2}\left(1+\frac{2h_l(T_1-T_2)}{\tau(h_1-h_2)}\;\frac{m}{M}-\frac{\partial m}{M}\;\frac{h_l}{h_1-h_2}\right)$$

Die Korrection wegen der Differenz der verdrängten Luft beträgt daher

$$-\frac{\delta m}{M}\ \frac{h_1}{h_1-h_2}L$$

Es sei das Volumen des Pendels $=V$; dann ist

$$\delta m=\rho_l\frac{\delta p}{p}V$$

$$M=\rho V$$

wo ρ_l die Dichtigkeit der Luft, ρ diejenige des ganzen Pendels, und p den Luftdruck bezeichnen. Für das Sekundenpendel ist

$$h_1 \doteq \frac{L}{2};$$

folglich wird die Korrection

$$=-\frac{\rho_l}{\rho}\ \frac{\delta p}{p}\ \frac{L^2}{2(h_1-h_2)}$$

für das Sekundenpendel.

Für $\delta p=1mm.$ Quecksilbergewicht beträgt die Korrection für die Länge des Sekundenpendels

$$-0{,}000305mm.$$

Ausgedrückt als Unterschied in der Schwingungsdauer ist diese Korrection gleich

$$-0{,}00000015\ sek.$$

wenn der Druck grösser ist für T_2 wie für T_1.

Für das Halbsekundenpendel geht diese Korrection über in

$$-0{,}00000001,$$

was vernachlässigt werden kann.

Wie schon oben bemerkt wurde, waren wir genötigt besonders auf die seismische Witterung während der Schwingungsbeobachtung zu achten. Es war sehr leicht ein Erdbeben, welches durch unser Gefühl wahrnehmbar ist, jedesmal zu berücksichtigen, da man die Störung durch die Verschiebung des Pendellagers und die gleichzeitig eintretende plötzliche Aenderung der Schwingungsamplitude und dergleichen Anzeichen leicht constatiren kann. Es wurde aber nicht selten ein heftigerer Erdstoss während der Schwingungsbeobachtung bemerkt. So unangenehm es auch auf dem ersten Augenblick erscheinen mag, muss man solche Beobachtungen ignoriren, da diese keinen Wert besitzen. Es hat sich aber nach mancher Erfahrung erwiesen, dass man bisweilen grosse Abweichungen in der Schwingungsdauer des Pendels beobachtet, ohne etwa eine plötzliche Aenderung des Uhrgangs oder den Erdstoss selbst zu bemerken. Solche Störungen wurden gewöhnlich durch ein sehr langsam verlaufendes Erdbeben verursacht; solche Schwankungen des Erdbodens werden nicht als Stoss unserem Körper fühlbar, sondern erscheinen als horizontale Bewegungen von colossaler Amplitude, wie sie auf dem Horizontalpendelseismometer registrirt wurden. Es ist deren langer Periode zuzuschreiben dass die Bewegung uns nicht zum Bewusstsein kommt. Trotzdem konnte man sehr leicht die Wirkung dieser Bodenschwankung auf die Schwingungsamplitude verspüren, da das Pendel einigermassen durch die Bewegung beeinflusst wird. Während der Beobachtung der Schwingungsdauer hat einer von uns (N) ganz ohne Absicht eine schöne Erfahrung gemacht, gelegentlich des grossen Erdbebens in Alaska am 11ten September 1899. Ein von der Ferne herkommendes Erdbeben ist gewöhnlich von sehr langer Periode; aber in Tōkyō, wo der Boden nicht sehr fest ist, sieht man mit dem besonders als Registririnstrument ausgestatteten Horizontalpendel, die beinahe als Sinuscurve verlaufende Schwankung

des Bodens. Diese Bewegung ist keineswegs stossartig, sodass sie für unseren Körper ganz unwahrnehmbar ist ; infolge dessen ist es ziemlich schwer die dadurch verursachte Unregelmässigkeit der Schwingungsdauer zu constatiren, da solche Störung nur um einen kleinen Betrag Aenderungen hervorruft. Als ein Beispiel sei die folgende Beobachtung des Koincidenzintervalls gegeben.

Ort : Physik. Institut, Universität zu Tōkyō, Beob : H. N.

Datum : 11ten Sept., 1899. Chronometer : Negus 1891.

Pendel : Sekundenpendel. Schneidencombn. u. Lage : I. F. o. h.

	Mittl. Zeit.	Thermometer.		Barometer.	Hygrometer.	Ausschlag.
		oben.	unten.			
Anfang	6ʰ 41.8ᵐ v	21.62°	21.60°	756.8 mm	21.00°–21.55°	1.75 × 14.′3
Ende	7 32.1 ,,	21.60	21.60	756.8	21.10–21.65	0.98 × ,,
Mittel	7 7.0 ,,	21.61	21.60	756.8	21.05–21.60	1.31 × ,,
Corr. u.s.w.	0.0	−0.08	−0.08	− 0.6	0.00 0.00	
Corrig.	7 7.0 ,,	21.53	21.52	756.2	18.0 mm	18.′7

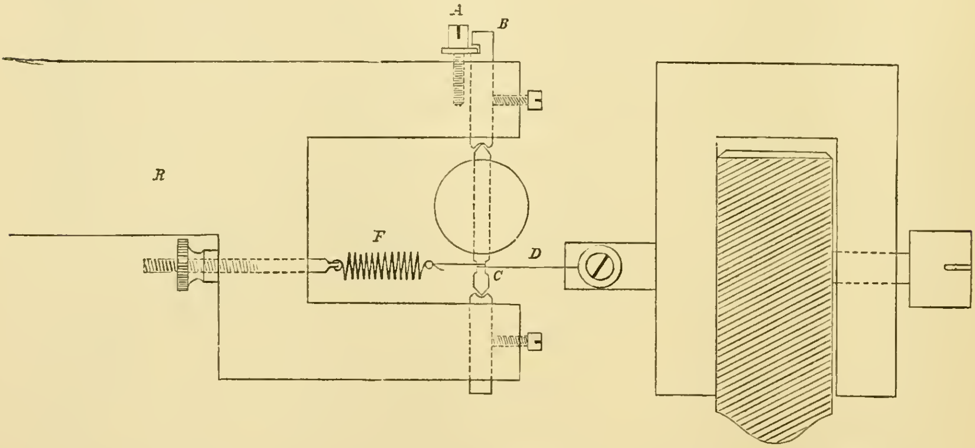
Nr.	Koincidenz.	Nr.	Koincidenz.	10 Koinc. interv.
1	5ʰ 15ᵐ 56.4ˢ	11	5ʰ 42ᵐ 28.7ˢ	26ᵐ 32.3ˢ
2	18 35.2	12	45 8.0	32.8
3	21 14.0	13	47 46.8	32.8
4	23 53.0	14	50 26.0	33.0
5	26 32.7	15	53 5.7	33.0
6	29 12.5	16	55 44.5	32.0
7	31 52.0	17	58 22.0	30.0
8	34 31.0	18	6 1 1.0	30.0
9	37 10.1	19	3 42.2	32.1
10	39 49.1	20	6 20.4	31.3
Mittel				26 31.93

Die horizontale Bewegung des Bodens ist in Tafel I gegeben, wie sie von Herrn Prof. Ōmori mit seinem Horizontalpendel registrirt worden ist.

Nachdem diese Bodenschwankung vorübergegangen war, wurde die Schwingungsdauer neu bestimmt und daraus gefunden, dass die Störung die Periode um $70 \times 10^{-7} sek.$ verringert hatte. Vor solcher Bodenschwankung muss man immer gewarnt sein, und jedesmal dass solche Störung vorkommt, muss man die Beobachtung unterbrechen. Jeder Schwereforscher in Japan ist genötigt das Seismometer mitzunehmen, damit seine Beobachtung von dieser Störung frei sei. Wir haben stets ein kleines Seismometer zur Seite gehabt und dessen Bewegung von Zeit zu Zeit beobachtet; wo möglich, ist es bequem das Seismometer selbstregistrend zu bauen, und auf demselben Pfeiler wie das Pendel das Instrument aufzustellen. In Kyōto und Kanazawa ist uns solche Störung nicht begegnet, aber in Mizusawa haben wir eine ausserordentlich grosse Aenderung der Schwingungsdauer bemerkt, welche wir nachher auf die Bodenschwankung zurückzuführen Grund hatten. Ferner haben wir gefunden dass eine kleine Bodenerschütterung, die sehr schwer zu vermeiden ist, das Pendel nicht stark beeinflusst, wenn es mit grosser Amplitude schwingt. Deswegen war es immer ratsam mit passendem Schwingungsbogen zu beobachten, da die Korrection auf unendlich kleine Amplitude nicht beträchtlich ist und ferner mit grosser Genauigkeit sich angeben lässt. Die Gestalt der Schneide wird sich aber etwas geltend machen, aber wir glauben dass der Vorteil, der durch grössere Schwingungsamplitude erzielt wurde, viel bedeutender ist als der nachteilige Einfluss, welcher von der Schneidengestalt herrührt. Gewöhnlich wurden beide Pendel mit der mittleren Amplitude von ungefähr 20 Bogenminuten in Bewegung versetzt.

Bestimmung der Mitschwingungscorrection.

Diese wichtige Korrection wurde nach einem anderen Verfahren ermittelt, wie es schon von verschiedenen Forschern vorgeschlagen worden ist. Im Wesentlichen beruht die hier benutzte Methode auf der Bestimmung der dem Pendelstativ durch die bekannte Zugkraft erteilte Verschiebung, die sich äusserst leicht und mit grosser Genauigkeit beobachten lässt. Schon Hertz hat, in seinem Elektrodynamometer, eine Methode angezeigt, wie man mit einem feinen Draht, der um einen anderen umgewunden ist, die Verschiebung des ersteren durch die Drehung des letzteren, wie man sie mittelst der Spiegelablesung beobachtet, stark vergrössern kann. Unser Verfahren beruht auf demselben Princip, welches von Hertz schon angewandt war.



Ein kleiner Cylinder (C) (0,80*mm.* Durchmesser) aus Wolframstahl wurde an beiden Enden zugespitzt und zwischen zwei kegelförmigen Achatpfannen gelegt. Diese Achatpfannen wurden im Messingcylinder eingelegt, welcher durch eine Adjustirschraube (A) einer sehr feinen Bewegung, ohne sich zu drehen, längs der Cylinderaxe fähig ist. Um den Cylinder (C) wurde ein feiner Draht (Durchmesser 0,08*mm.*) umgewunden; der Draht endigt in einer

schwachen Spiralfeder während das andere Ende dem Pendellager fest angeschraubt wurde. Wenn der Lager sehr wenig verschoben wird, so macht die Feder, die in der Verlängerung des Drahtes ruht, die Bewegung mit, und der Betrag dieser Verschiebung wurde durch die Drehung eines leichten Spiegels gemessen, welcher an dem Cylinder (C) festgekittet ist. Der starke Messingrahmen, welcher diese Vorrichtung trägt, wurde an einem soliden Dreifuss, welches als ein fester Punkt betrachtet werden kann, angeschraubt. Wenn man an dem Pendellager mit einem starken Faden in der Richtung der Pendelbewegung zieht, so beobachtet man die Drehung des Spiegels, welche mit Scala und Fernrohr ermittelt werden kann. Die Verschiebung von 4,6*mm.* in 1*m.* Abstand entspricht bei dem von uns gebrauchten Apparat der Verschiebung um 1μ. Wenn die Mitschwingung ziemlich stark ist, so konnte man die hin-und herschwingende Bewegung der Konsole, die durch das Pendel hervorgerufen wird, leicht beobachten. Man kann dadurch entweder die statische oder die dynamische Constante in die Rechnung der Correction einführen.

Zur Berechnung der Correction, denkt man sich die Verschiebung durch den Zug von 1 *kg.* gewicht $=\varepsilon$, und das Gewicht des Pendels $=w$, dann beträgt die Correction für die Länge des Sekundenpendels

$$\delta L = w\varepsilon \frac{L}{\Lambda}.$$

Der Pendelpfeiler war ziemlich fest gebaut, so dass die Mitschwingung nur eine sehr kleine Aenderung in Schwingungsdauer hervorbrachte, in allen Messungen die wir ausgeführt haben.

Längenmessung.

Zur Bestimmung der Pendellänge diente eine Phosphorbroncescala, welche 102*cm.* lang war. Der Querschnitt war H-förmig mit

einblegtem Silberblech in der Ebene der Nullelongation, auf welche feine Linien mit je 1*mm*. Intervall eingeritzt waren ; ein Ende der Scala wurde in $\frac{1}{10}$*mm*. geteilt und diente zur Bestimmung der Constante des Micrometers, welches dem Vertikalcomparator angehört. Diese Scala wurde im Bureau international des poids et mesures in Sèvres, von Herrn Ch. Ed. Guillaume genau untersucht und hat die folgende Correction, die wir benutzten.

Teilstrich.	Correction.
	μ
25 *cm*.	+5,5
75 *cm*.	+1,8
100 *cm*.	−0,3

Der Ausdehungscoefficient α betrug

$$\alpha = 0{,}000016502 + 0{,}00000000625t$$

mit dem Thermometer à verre dur.

Diese Correction ist nur bei der horizontalen Lage der Scala anzuwenden, so dass man noch eine Correction wegen der Verkürzung einzuführen hat, da die Scala während der Messung immer vertikal aufgehalten war. Die Verkürzung beträgt nur $0{,}3\mu$ für 1*m*.

Wie bei der Längenmessung üblich ist, wurde nach der gewöhnlichen Methode, die Pendelschneide bei dunkler sowie bei heller Beleuchtung gemessen. In letzterem Falle wurde die Schneide mit einer kleinen elektrischen Lampe beleuchtet, welche in solcher Entfernung aufgestellt wurde, dass die Temperatur des Pendels nicht merklich afficirt war. Fast alle Beobachtungen zeigen dass die Länge bei dunklen Schneiden grösser ist als bei den hellen, wie es von mehreren Beobachtern constatirt worden ist.

Die schwierigste Aufgabe bei dieser Messung war die Ermittelung der genauen Temperatur des Pendels. Bei dem Sekundenpendel wurden einige Thermometer neben dem Pendel und der Scala auf-

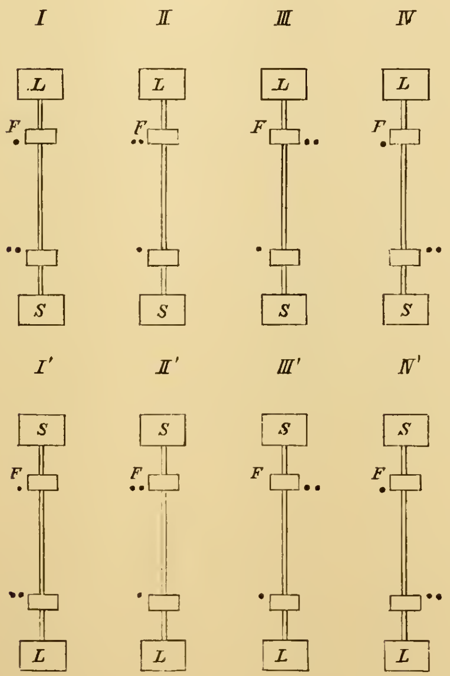
gehängt, wie in der Figur, welche der Tabelle (*w.u.*) hinzugefügt ist, angedeutet wird.

Die Temperaturdifferenz zwischen diesen Thermometern war gewöhnlich nicht grösser als 0°,2*C*. Diese Thermometer wurden oftmals mit dem Etalon verglichen und corrigirt.

Es war ein grosser Vorteil für uns gewesen, dass wir bei Sommerhitze gearbeitet haben, da der Einfluss der Körperwärme auf die Temperatur der Scala und des Pendels infolgedessen äusserst gering war. Bei den Beobachtungen, wobei die Temperatur der Umgebung unter 20° blieb, fand man gewöhnlich einen allmählichen Temperaturaufsteig.

Der Wert eines Teilstriches der Micrometertrommell betrug ungefähr 1μ; diese Constante wurde durch die in $\frac{1}{10}$*mm.* geteilten Teile der Meterscala ermittelt.

Die Verschiedene Combination der Pendelschneide und der Gewichte, wobei wir die Schwingungsbeobachtungen und die Längenmessung ausgeführt haben, wird aus der Figur klar.



Die Punkte beziehen sich auf die Schneiden, welche resp. durch einen [·] und zwei [··] Punkte unterschieden waren.

Die Lage des Schwerpunktes wurde mit dem Apparat, der zu diesem Zwecke besonders construirt war, ermittelt. Bei der verschiedenen Combinationen der Schneiden und der Gewichte ergab sich folgendes Resultat.

Lage des Schwerpunktes (bei 0°)

Sekundenpendel.			Halbsekundenpendel.		
Combination der Pendel-schneide.	h_1	h_2	Combination der Pendel-schneide.	h_1	h_2
	mm	mm		mm	mm
I	702,6	297,2	I	159,9	90,0
II	702,6	297,3	II	159,9	90,0
III	702,6	297,3	III	159,9	90,0
IV	702,6	297,3	IV	159,9	90,0
I′	703,5	296,3	I′	160,0	89,9
II′	703,5	296,4	II′	160,1	89,8
III′	703,5	296,4	III′	160,1	89,9
IV′	703,5	296,4	IV′	160.0	89,9

Was den wahrscheinlichen Fehler der Schlussresultate anbelangt, so sieht man auf der Stelle dass derjenige der Biegungscorrection alle anderen der Messresultate übersteigt. Auf rohe Schätzung dieses Fehlers hin kann man ihn nur auf $\pm 15\mu$ in L angeben, infolge der Unsicherheit in der Dichtigkeitsbestimmung, in der Elasticitäts-constante und in der gebrauchten Formel. Der tägliche Gang des Chronometers wird einen Fehler verursachen, welcher den der Biegungscorrection zunächst kommt. Trotzdem ist die Grösse der letzteren äusserst gering gegen die ersten, sodass man den Fehler der Schlussresultate beinahe gleich demjenigen für die Biegungscorrection ansehen kann.

KYŌTO.

Der Pendelraum (Tafel II) liegt neben dem grossen Hörsaal des physikalischen Intituts der kaiserlichen Universität zu Kyōto. Der Granitpfeiler für das Pendel wurde in der Mitte des Saals aufgestellt, nach dem in der Figur gegebenen Plane. Die tägliche Variation der Temperatur innerhalb des Beobachtungsraumes war äusserst gering und überstieg selten 0°,5 *C*.

Das Institut wurde gebaut auf einem Boden, welcher ziemlich fest ist; er besteht bis zur Tiefe von einigen Metres aus gross körnigem Kies. Die Station liegt auf einer Ebene, welche einen Teil des Thals bildet, welcher nord-östlich von der Hiyei-, und nord-westlich von der Kurama-Kette begrenzt ist; südlich liegen die Berge ziemlich weit von der Stadt ab. Die Anziehung dieser höhen Gebirge wird sich etwas auf g geltend machen, aber in Ermangelung genauer Kenntniss der Dichtigkeit, haben wir darauf verzichtet diese Korrection in die Rechnung einzuführen.

Tabellarisch dargestellt, lauten die Resultate der verschiedenen Messungen folgendermassen:—

Station : Breite : 35° 1′,6
Länge : 9^h 3^m $8^s,5$ östlich von Greenwich.
Höhe : 55^m ; $\theta = 2,0$

Physikalisches Institut der Universität zu Kyōto.

Datum : 14ten Juli bis 2ten August, 1899.
Beobachter : H. Nagaoka, R. Ōtani und S. Shinjō.

Instrumente.

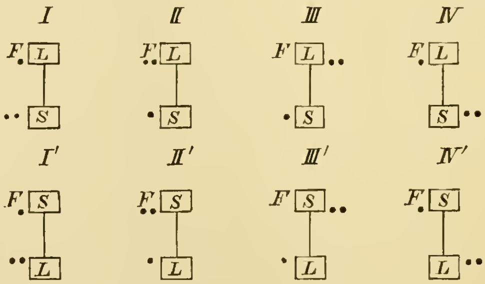
Chronometer : Negus No. 1891 für Koincidenzbeobachtung.
„ „ 1622 „ astronomische Beobachtung.

Durchgangsinstrument : Troughton und Simms.

Thermometer :	Gerhardt 4242	Gerhardt 4243	Démichel 3898	Démichel 3893	Démichel 2586
Corrn. bei 27°	$-0\overset{\circ}{,}06$	$-0\overset{\circ}{,}07$	$-0\overset{\circ}{,}03$	$-0\overset{\circ}{,}03$	$-0\overset{\circ}{,}23$

Barometer : Quecksilber Barometer mit Corrn. $-0,30$ mm.
Hygrometer : Psychrometer.
Seismometer : Horizontalpendel.

Schneiden-combination des Pendels.



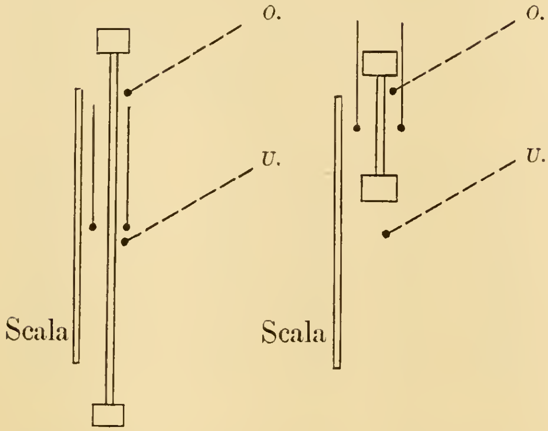
L bedeutet leichtes Gewicht.

S bedeutet schweres Gewicht.

Biegungscorrection :	Correction für	Sekundenpendel	-329	μ	in L
	„ „	$\frac{1}{2}$s. pendel	$-\ \ 2$	μ	„ „
Mitschwingungscorrection :	„ „	Sekundenpendel	$+\ \ 2,6$	μ	„ „
	„ „	$\frac{1}{2}$s. pendel	$+\ 10,5$	μ	„ „

Micrometer : Oben : $100^p = 100\overset{\mu}{,}30$ bei 24°
Unten : $100^p = 100,34$ „ „

Lage der Thermometer:



(Für die Bestimmung der Schwingungsdauer, ist die Lage der Thermometer mit Strichlinien von derjenigen bei der Längenmessung unterschieden.)

Täglicher Gang des Chronometers Negus No. 1891.

Datum (S.Z.)		ΔT	Differenz.	Mittler täglicher Gang.
1899-Juli-14	$15^{h},0$	$+43^{m}\ 13^{s},77$	$1^{s},12$	$1^{s},10$
15	15,5	14,89	1,33	1,23
16	17,5	16,22	3,45	1,16
19	16,7	19,67	4,59	1,16
23	15,4	24,26	2,48	1,23
25	15,6	26,74	2,40	1,19
27	15,9	29,14	1,06	1,09
28	15,3	30,20	1,66	1,66
29	15,4	31,86	1,51	1,44
30	16,5	33,37	2,44	1,18
August 1	18,2	35,81	1,69	1,73
2	17,7	37,50		

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.	Koinc.-intervall.	Stangentemp. o.	Stangentemp. u.	Stangentemp. $\frac{(o)+3(u)}{4}$	Aus-schlag in der Mitte.	Luft-druck.
			s	°	°	°	′	mm
VII–14	S	I F.o.v.	156.591	26.85	26.66	26.71	19.2	753.4
,,	S	,, F.u.v.	156.809	27.05	26.84	26.89	19.5	753.3
,,	S	,, F.u.h.	156.726	27.23	27.01	27.07	18.3	753.5
,,	S	,, F.o.h.	156.449	27.11	26.89	26.95	19.3	753.7
VII–23	S	,, F.o.v.	156.758	26.12	26.02	26.05	19.5	743.8
,,	S	,, F.u.v.	157.132	26.15	26.03	26.06	18.6	743.5
,,	O	,, F.u.h.	157.234	26.32	26.12	26.17	17.4	743.2
,,	O	,, F o.h.	156.813	26.41	26.24	26.28	18.4	743.2
VII–15	O	I′ F.u.v.	156.814	27.06	26.84	26.90	19.0	753.5
,,	O	,, F.o.v.	156.966	27.25	27.01	27.07	19.7	753.1
,,	O	,, F.o.h.	156.840	27.36	27.11	27.17	18.5	753.2
,,	O	,, F.u.h.	156.695	27.34	27.08	27.15	17.8	753.7
VII–23	N	,, F.o.v.	157.103	26.57	26.47	26.50	19.0	743.1
,,	N	,, F.u.v.	156.986	26.58	26.49	26.51	18.9	742.8
,,	S	,, F.u.h.	156.922	26.65	26.51	26.55	18.9	743.4
,,	S	,, F.o.h.	157.118	26.53	26.38	26.42	18.1	744.0
VII–17	N	II′ F.o.v.	157.006	26.87	26.76	26.79	19.3	751.5
,,	N	,, F.u.v.	156.550	27.17	27.01	27.05	18.8	751.0
,,	N	,, F.u.h.	156.585	27.30	27.13	27.17	19.1	750.0
,,	N	,, F.o.h.	156.988	27.46	27.26	27.31	19.3	749.3
VIII–1	O	,, F.o.v.	157.582	24.89	24.75	24.79	19.1	751.4
,,	O	,, F.u.v.	157.060	25.01	24.84	24.88	18.7	751.6
VII–17	S	II F.o.v.	156.442	27.62	27.40	27.46	19.6	750.5
,,	S	,, F.u.v.	156.480	27.44	27.19	27.25	19.0	751.2
,,	S	,, F.u.h.	156.428	27.24	27.02	27.08	19.1	751.7
,,	N	,, F.o.h.	156.472	27.13	26.93	26.98	19.6	752.0
VIII–1	S	,, F.o.v.	157.153	24.93	24.72	24.77	19.1	752.4
,,	S	,, F.u.v.	157.000	24.79	24.59	24.64	18.6	753.1
,,	N	,, F.u.h.	157.221	23.95	23.87	23.89	18.4	753.6
,,	N	,, F.o.h.	157.235	24.00	23.91	23.93	19.6	753.9

SEKUNDENPENDEL. (Kyōto).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 27°	T	τ'	Korrection wegen Druck-unterschied.	τ in Stern-zeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		s
20.5	1.0064271	+128	−20	+27	1.0064406	1.0064185	0	1.0064485
20.9	181	+128	−21	+10	298			
20.5	215	+128	−18	−7	318	535	0	535
21.3	330	+128	−20	+5	443			
21.3	202	+135	−21	+88	404	515	0	515
21.3	048	+135	−19	+88	252			
21.4	006	+135	−17	+77	201	484	0	484
21.2	180	+135	−18	+67	364			
								1.0064505
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
21.5	1.0064179	+128	−20	+9	1.0064296	1.0064354	−1	1.0064353
21.9	117	+128	−21	−7	217			
22.3	169	+128	−19	−16	262	369	−1	368
22.1	228	+128	−18	−14	324			
21.1	060	+135	−20	+47	222	305	0	305
21.1	108	+135	−19	+46	270			
20.7	135	+135	−19	+42	293	343	+1	344
20.7	054	+135	−18	+54	225			
								1.0064343
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
22.4	1.0064100	+135	−20	+20	1.0064235	1.0064519	+1	1.0064520
22.5	4288	+135	−19	−5	399			
22.6	4273	+135	−20	−16	372	502	−1	501
22.7	4108	+135	−20	−29	194			
19.2	3864	+137	−20	+206	187	543	0	543
19.3	4078	+137	−19	+197	393			
								1.0064521
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
22.2	1.0064333	+135	−21	−43	1.0064404	1.0064400	+1	1.0064401
22.4	317	+135	−20	−23	409			
22.3	338	+135	−20	−7	446	429	0	429
22.4	320	+135	−21	+2	436			
19.4	040	+137	−20	+207	364	308	+1	309
19.2	103	+137	−19	+219	440			
17.6	012	+137	−18	+289	420	397	0	397
17.8	006	+137	−21	+285	407			
								1.0064384

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-intervall.	Stangentemp. o.	Stangentemp. u.	Stangentemp. $\frac{(o)+3(u)}{4}$	Aus-schlag in der Mitte.	Luft-druck.
					°	°	°	′	mm
VII–18	O	III	F.o.v.	156.579	27.57	27.42	27.46	19.3	751.4
,,	O	,,	F.u.v.	156.459	27.30	27.13	27.17	17.5	751.7
VII–19	N	,,	F.u.h.	156.751	26.98	26.89	26.91	16.2	752.9
,,	N	,,	F.o.h.	156.654	27.20	27.08	27.11	19.3	752.5
VII–24	O	,,	F.o.v.	156.959	25.83	25.63	25.68	19.1	744.3
,,	O	,,	F.u.v.	156.876	25.78	25.56	25.62	17.8	744.0
,,	S	,,	,,	156.848	25.76	25.64	25.67	19.3	743.7
VII–19	S	III′	F.u.v.	156.646	27.32	27.18	27.22	19.3	752.1
,,	S	,,	F.o.v.	157.125	27.40	27.26	27.30	18.6	751.5
,,	O	,,	F.o.h.	157.098	27.48	27.37	27.40	18.7	752.1
,,	O	,,	F.u.h.	156.546	27.50	27.38	27.41	18.7	752.4
VII–20	N	IV′	F.o.v.	156.706	27.68	27.49	27.54	18.6	750.2
,,	N	,,	F.u.v.	156.484	27.67	27.46	27.51	19.3	749.9
,,	S	,,	F.u.h.	156.610	27.62	27.42	27.47	19.3	749.9
,,	S	,,	F.o.h.	156.740	27.55	27.40	27.44	18.6	750.1
VIII–1	N	,,	F.o.v.	157.228	24.83	24.68	24.72	17.4	751.6
,,	N	,,	F.u.v.	157.225	24.77	24.66	24.69	19.9	751.4
VII–21	O	IV	F.o.v.	156.448	27.34	27.15	27.20	18.9	748.4
,,	O	,,	F.u.v.	156.721	27.41	27.21	27.26	19.5	748.2
,,	N	,,	F.u.h.	156.687	27.46	27.36	27.39	17.7	747.7
,,	N	,,	F.o.h.	156.400	27.58	27.45	27.48	19.6	746.5

SEKUNDENPENDEL. (Kyōto).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Sternzeit.	Reduction für α	Reduction auf 27°	T	τ'	Korrection wegen Druck-unterschied.	τ in Sternzeit-sek.
mm 22.0	s 1.0064276	+135	−20	−43	s 1.0064348	$\left(\frac{h_2}{h_1-h_2}=0.733\right)$ 1.0064289	0	s 1.0064289
21.8	326	+135	−17	−16	428			
22.0	205	+135	−15	+8	333	362	+1	363
22.4	245	+135	−20	−10	350			
19.7	119	+143	−20	+123	365			
19.9	154	+143	−17	+128	408	332	−1	331
19.5	165	+143	−20	+124	412			**1.0064328**
22.6	1.0064249	+135	−20	−20	1.0064344	$\left(\frac{h_2}{h_1-h_2}=0.728\right)$ 1.0064493	−1	1.0064492
22.7	051	+135	−19	−28	139			
23.0	062	+135	−19	−37	141	533	0	533
22.9	290	+135	−19	−38	368			**1.0064513**
22.8	1.0064224	+135	−19	−50	1.0064290	$\left(\frac{h_2}{h_1-h_2}=0.728\right)$ 1.0064451	0	1.0064451
23.2	315	+135	−20	−47	383			
23.1	263	+135	−20	−44	334	370	0	370
23.3	210	+135	−19	−41	285			
19.1	009	+137	−17	+212	341	341	0	341
19.4	010	+137	−21	+215	341			**1.0064387**
23.6	1.0064330	+135	−19	−19	1.0064427	$\left(\frac{h_2}{h_1-h_2}=0.733\right)$ 1.0064514	0	1.0064514
23.8	218	+135	−21	−24	308			
23.9	231	+135	−17	−36	313	499	+2	499
23.9	350	+135	−21	−45	419			**1.0064507**

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-intervall.	Stangentemp. o.	Stangentemp. u.	Stangentemp. $\frac{4(o)+(u)}{5}$	Ausschlag in der Mitte.	Luftdruck.
				s		°	°	′	mm
VII-26	O	I	F.o.v.	77.583	……	25.18	25.34	18.7	748.1
,,	O	,,	F.u.v.	77.990	……	25.25	25.41	19.9	747.8
,,	S	,,	F.u.h.	78.022	……	25.22	25.38	18.9	747.7
,,	S	,,	F.o.h.	77.618	……	25.22	25.38	19.5	747.9
VII-27	N	I′	F.o.v.	77.859	……	24.84	25.00	19.7	748.1
,,	N	,,	F.u.v.	78.040	25.07	24.97	25.05	19.0	747.9
,,	O	,,	F.u.h.	78.004	25.15	24.97	25.11	19.5	747.5
,,	O	,,	F.o.h.	77.845	25.27	25.08	25.23	19.7	747.0
VII-27	S	II′	F.o.v.	78.326	25.14	24.92	25.10	19.1	747.7
,,	S	,,	F.u.v.	77.761	25.32	25.09	25.27	19.2	747.5
VII-28	N	,,	F.u.h.	77.899	24.23	24.18	24.22	19.4	748.9
,,	N	,,	F.o.h.	78.410	24.38	24.28	24.36	19.4	748.9
VII-28	S	II	F.o.v.	78.073	24.56	24.41	24.53	19.1	748.4
,,	S	,,	F.u.v.	77.838	24.67	24.52	24.64	19.5	747.9
,,	O	,,	F.u.h.	77.704	25.05	24.85	25.01	19.6	748.5
,,	O	,,	F.o.h.	77.973	25.05	24.86	25.01	19.3	748.2
VII-29	N	III	F.o.v.	78.020	24.91	24.77	24.88	19.7	750.9
,,	N	,,	F.u.v.	77.688	24.95	24.77	24.91	20.0	750.6
,,	O	,,	F.u.h.	77.676	25.00	24.80	24.96	19.8	750.0
,,	O	,,	F.o.h.	77.979	25.18	24.98	25.14	19.3	749.6
VII-29	N	III′	F.o.v.	78.186	25.37	25.13	25.32	19.9	749.8
VII-31	S	,,	,,	78.226	25 37	25.18	25.33	18.3	750.5
VII-29	S	,,	F.u.v.	77.837	25.32	25.07	25.27	19.2	750.4
,,	S	,,	F.u.h.	77.837	25.25	25.02	25.20	19.2	751.1
,,	S	,,	F.o.h.	78.299	25.17	24.95	25.13	18.9	751.6

HALBSEKUNDENPENDEL. (Kyōto).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Sternzeit.	für α	auf 25°	T	τ'	Korrection wegen Druckunterschied.	τ in Sternzeit-sek.
mm	s				s			s
						$\left(\frac{h_2}{h_1-h_2}=1.290\right)$		
19.3	0.5032433	+69	−10	−16	0.5032476	0.5032701	0	0.5032701
19.3	263	+69	−11	−19	302			
19.3	249	+69	−10	−17	291	678	0	678
19.3	418	+69	−10	−17	460			
								0.5032690
						$\left(\frac{h_2}{h_1-h_2}=1.281\right)$		
19.5	0.5032317	+69	−11	0	0.5032375	0.5032202	0	0.5032202
19.5	242	+69	−10	−2	299			
19.7	257	+69	−10	−5	311	235	0	235
19.6	323	+69	−11	−11	370			
								0.5032219
						$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		
18.6	0.5032123	+69	−10	−5	0.5032177	0.5032697	0	0.5032697
18.9	358	+69	−10	−12	405			
17.7	300	+63	−10	+36	389	668	0	668
17.7	089	+63	−10	+29	171			
								0.5032683
						$\left(\frac{h_2}{h_1-h_2}=1.288\right)$		
18.0	0.5032228	+63	−10	+22	0.5032303	0.5032183	0	0.5032183
17.7	326	+63	−10	+17	396			
18.2	382	+63	−10	−0	435	177	0	177
18.2	269	+63	−10	−0	322			
								0.5032180
						$\left(\frac{h_2}{h_1-h_2}=1.288\right)$		
18.2	0.5032250	+97	−11	+6	0.5032342	0.5032166	0	0.5032166
18.5	389	+97	−11	+4	479			
18.8	394	+97	−11	+2	482	175	0	175
18.9	267	+97	−10	−6	348			
								0.5032171
						$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		
18.4	0.5032181	+97	−11	−15	0.5032252	0.5032619	0	0.5032619
20.2	164	+69	−9	−15	209			
18.4	326	+97	−10	−12	401			
18.5	326	+97	−10	−9	404	646	0	646
19.0	134	+97	−10	−6	215			
								0.5032633

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.	Koinc.-intervall.	Stangentemp.			Aus-schlag in der Mitte.	Luft-druck.
				o.	u.	$\frac{4(o)+(u)}{5}$		
			s	°	°	°	′	mm
VII–30	N	IV′ F.o.v.	77.837	25.32	25.13	25.28	20.7	751.0
„	N	„ F.u.v.	78.074	25.36	25.17	25.32	18.5	751.1
„	O	„ F.u.h.	78.056	25.37	25.17	25.33	19.8	750.9
„	O	„ F.o.h.	77.819	25.37	25.17	25.33	18.8	751.9
VII–30	S	IV F.o.v.	77.676	25.43	25.19	25.38	19.0	751.4
„	S	„ F.u.v.	78.132	25.36	25.19	25.33	19.5	751.5
VII–31	O	„ F.u.h.	78.196	24.92	24.72	24.88	18.3	751.8
„	O	„ F.o.h.	77.736	25.06	24.87	25.02	19.4	751.8

HALBSEKUNDENPENDEL. (Kyōto.)

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 25°	T	τ'	Korrection wegen Druck-unter-schied.	τ in Stern-zeit-sek.
mm 18.9	s 0.5032326	+84	−11	−13	s 0.5032386	$\left(\frac{h_2}{h_1-h_2}=1.280\right)$ 0.5032162	0	s 0.5032162
19.0	228	+84	−9	−15	288			
19.3	235	+84	−11	−15	293	165	0	165
19.3	334	+84	−10	−15	393			
								0.5032164
19.5	0.5032393	+84	−10	−17	0.5032450	$\left(\frac{h_2}{h_1-h_2}=1.288\right)$ 0.5032692	0	0.5032692
19.3	203	+84	−10	−15	262			
19.5	177	+69	−9	+6	243	664	0	664
19.6	369	+69	−10	−1	427			
								0.5032678

LÄNGENMESSUNG SEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VII-22	S	I F.u.v.	26.86	26.90	−112.9		26.92	26.94	−109.4
,,	O	,, F.o.v.	27.03	27.03	−105.3		27.00	27.01	−106.3
,,	N	,, F.o.h.	26.97	27.02	−112.6		26.93	26.98	−108.6
,,	O	,, F.u.h.	26.97	27.00	−106.9		27.01	27.01	−110.4
,,	N	,, F.u.h.	26.93	26.99	−112.6		26.94	26.99	−111.1
,,	S	,, F.o.h.	26.97	27.02	−109.7		26.97	27.01	−110.8
,,	S	,, F.o.h.	26.82	26.88	−107.4		26.87	26.92	−115.6
			26.94	26.98	−109.6		26.95	26.98	−110.3
		Länge der Scala	1.0004491				1.0004491		
		Micro-Ablesung	−1096				−1103		
		Red. auf 27°	+ 11				+ 9		
		Λ bei 27°	1.0003406				1.0003397		
		Mittel				m 1.0003402			
VII-16	N	I′ F.o.v.	27.25	27.28	−109.2		27.23	27.29	−109.5
,,	O	,, F.u.v.	27.27	27.28	− 99.1		27.29	27.31	− 94.0
,,	S	,, F.u.h.	27.26	27.29	− 94.3		27.28	27.30	−106.0
,,	N	,, F.o.h.	27.40	27.42	− 97.6		27.40	27.41	−101.9
VII-24	S	,, F.o.v.	25.65	25.69	−118.6		25.71	25.73	−119.2
,,	N	,, F.u.v.	25.74	25.79	−116.4		25.78	25.83	−114.6
,,	S	,, F.u.h.	25.89	25.91	−110.9		25.87	25.91	−109.5
,,	N	,, F.o.h.	25.86	25.90	−110.7		25.85	25.89	−110.3
			26.54	26.57	−107.1		26.55	26.58	−108.1
			1.0004422				1.0004423		
			−1071				−1081		
			+ 85				+ 83		
			1.0003436				1.0003425		
						1.0003431			

LÄNGENMESSUNG SEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Beleuchtung dunkel. Temp. Scala.	Beleuchtung dunkel. Micro-abl.		Beleuchtung hell. Temp. Pendel.	Beleuchtung hell. Temp. Scala.	Beleuchtung hell. Micro-abl.
VII–16	O	II′ F.o.h.	27.49	27.50	− 99.8		27.51	27.53	−101.3
„	S	„ F.u.h.	27.54	27.54	−103.7		27.51	27.53	−100.1
„	N	„ F.u.v.	27.59	27.59	−101.9		27.57	27.58	− 99.6
„	O	„ F.u.h.	27.58	27.59	−102.4		27.59	27.60	− 98.4
„	S	„ F.o.v.	27.73	27.74	−108.8		27.65	27.66	−103.1
			27.59	27.59	−103.3		27.57	27.58	−100.5
		Länge der Scala		1.0004593				1.0004592	
		Micro-Ablesung		−1033				−1005	
		Red. auf 27°		− 109				− 106	
		Λ bei 27°		1.0003451		m		1.0003481	
		Mittel				**1.0003466**			
VII–18	O	II F.u.v.	26.97	26.97	−101.0		26.98	26.98	− 97.7
„	S	„ F.u.h.	27.15	27.17	−106.2		27.08	27.12	−102.9
„	N	„ F.o.h.	27.11	27.15	−101.2		27.05	27.11	−111.2
„	O	„ F.o.v.	27.16	27.17	−101.5		27.12	27.15	−105.0
„	N	„ F.o.h.	27.12	27.18	−106.0		27.16	27.20	−106.6
			27.10	27.13	−103.2		27.08	27.11	−104.7
				1.0004516				1.0004513	
				−1032				−1047	
				− 19				− 15	
				1.0003465				1.0003451	
						1.0003458			
VII–18	S	III F.o.v.	27.31	27.31	−109.2		27.32	27.32	−110.7
„	O	„ F.u.v.	27.41	27.44	−104.5		27.42	27.46	−106.2
„	N	„ F.u.h.	27.45	27.50	−102.6		27.41	27.46	−101.8
„	S	„ F.o.h.	27.49	27.50	−102.1		27.50	27.48	− 96.0
			27.42	27.44	−104.6		27.41	27.43	−103.7
				1.0004568				1.0004567	
				−1046				−1037	
				− 78				− 76	
				1.0003444				1.0003454	
						1.0003449			

LÄNGENMESSUNG SEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel	Scala.			Pendel.	Scala.	
VII-20	O	III' F.o.v.	27.29	27.29	−104.3		27.27	27.28	−103.0
„	S	„ F.u.v.	27.33	27.35	−102.8		27.31	27.34	−109.1
„	N	„ F.u.h.	27.35	27.42	−102.9		27 35	27.43	−106.3
„	O	„ F.o.h.	27.41	27.50	−103.5		27.38	27.46	−102.8
			27.35	27.39	−103.4		27.33	27.38	−105.3
		Länge der Scala		1.0004560				1.0004558	
		Micro-Ablesung		−1034				−1053	
		Red. auf 27°		− 65				− 61	
		Λ bei 27°		1.0003461				1.0003444	
		Mittel				m 1.0003453			
VII-20	S	IV' F.u.v.	27.43	27.47	− 97.6		27.44	27.47	−106.6
„	N	„ F.o.v.	27.48	27.53	−107.2		27.44	27.52	−107.0
„	O	„ F.o.h.	27.50	27.54	−105.1		27.44	27.49	−107.0
„	S	„ F.u.h.	27.53	27.56	−102.5		27.51	27.55	−106.7
			27.49	27.53	−103.1		27.46	27.51	−106.8
				1.0004584				1.0004580	
				−1031				−1068	
				− 91				− 85	
				1.0003462				1.0003427	
						1.0003445			
VII-22	N	IV F.o.v.	26.78	26.80	−101.3		26.74	26.78	−104.4
„	S	„ F.u.v.	26.83	26.87	−105.6		26.85	26.89	−108.5
„	N	„ F.u.h.	26.90	26.95	− 93.9		26.92	26.97	−115.7
„	S	„ F.u h.	26.95	27.00	−105.1		26.95	27.00	−106.4
„	N	„ F.o.h.	27.01	27.04	−101.3		26.02	27.06	−105.0
			26.89	26.93	−101.4		26.90	26.94	−108.0
				1.0004482				1.0004484	
				−1014				−1080	
				+ 20				+ 19	
				1.0003488				1.0003423	
						1.0003456			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Beleuchtung dunkel. Temp. Scala.	Beleuchtung dunkel. Micro-abl.		Beleuchtung hell. Temp. Pendel.	Beleuchtung hell. Temp. Scala.	Beleuchtung hell. Micro-abl.
VII–26	N	I F.u.v.	25.27	25.27	−81.5		25.27	25.27	−79.8
„	S	„ F.o.v.	25.35	25.32	−83.1		25.36	25.35	−89.5
„	N	„ F.o.h.	25.28	25.28	−78.2		25.28	25.29	−86.4
„	S	„ F.u.h.	25.33	25.31	−79.8		25.37	25.36	−86.3
			25.31	25 30	−80.7		25.32	25.32	−85.5
		Länge der Scala			0.2501032				0.2501032
		Micro-Ablesung			−807				−855
		Red. auf 25°			− 10				− 15
		Λ bei 25°			0.2500211				0.2500162
		Mittel				m 0.2500187			
VII–27	S	I′ F.o.v.	25.63	25.60	−93.8		25.67	25.69	−88.4
„	N	„ F.u.v.	25.67	25.67	−88.4		25.67	25.67	−88.0
„	S	„ F.u.h.	25.67	25.71	−92.0		25.74	25.75	−89.4
„	N	„ F.o.h.	25.69	25.68	−90.1		25.74	25.73	−83.5
			25.67	25.67	−91.1		25.71	25.71	−87.3
					0.2501123				0.2501125
					−911				−873
					− 31				− 33
					0.2500181				0.2500219
						0.2500200			
VII–27	S	II′ F.o.v.	25.95	25.97	−87.7		25.92	25.96	−85.8
„	O	„ F.u.v.	25.88	25.92	−87.9		25.90	25.97	−88.8
„	S	„ F.u.h.	25.80	25.83	−84.6		25.83	25.88	−88.5
„	O	„ F.o.h.	25.82	25.87	−86.8		25.81	25.87	−88.7
			25.86	25.90	−86.8		25.87	25.92	−88.0
					0.2501133				0.2501134
					−868				−880
					− 40				− 40
					0.2500225				0.2500214
						0.2500220			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Scala.	Micro-abl.		Beleuchtung hell. Temp. Pendel.	Scala.	Micro-abl.
VII–29	N	II F.o.v.	24.33	24.38	−93.2		24.38	24.43	−88.7
,,	O	,, F.u.v.	24.46	24.51	−92.2		24.53	24.61	−94.2
,,	N	,, F.u.h.	24.54	24.60	−90.3		24.59	24.64	−91.8
,,	O	,, F.o.h.	24.65	24.72	−88.8		24.70	24.81	−89.4
			24.50	24.55	−91.1		24.55	24.62	−91.0
		Länge der Scala		0.2501076				0.2501079	
		Micro-Ablesun g		−911				−910	
		Red. auf 25°		+ 23				+ 21	
		Λ bei 25°		0.2500188				0.2500190	
		Mittel				$0.\overset{\mathrm{m}}{2}500189$			
VII–29	S	III F.o.v.	24.77	24.86	−92.9		24.80	24.89	−95.2
,,	O	,, F.u.v.	24.88	24.97	−90.9		24.92	25.01	−89.5
,,	S	,, F.u.h.	24.87	24.92	−86.3		24.95	25.02	−89.3
,,	O	,, F.o.h.	24.95	25.02	−87.9		25.01	25.11	−87.1
			24.87	24.94	−89.5		24.92	25.01	−90.3
				0.2501092				0.2501095	
				−895				−903	
				+ 6				+ 4	
				0.2500203				0.2500196	
						0.2500200			
VII–30	N	III′ F.o.v.	24.98	25.05	−95.6		25.00	25.10	−91.2
,,	O	,, F.u.v.	25.06	25.13	−90.1		25.11	25.21	−91.9
,,	N	,, F.u.h.	25.06	25.15	−88.0		25.10	25.18	−93.2
,,	O	,, F.o.h.	25.14	25.20	−90.5		25.17	25.23	−89.4
			25.06	25.13	−91.0		25.10	25.18	−91.4
				0.2501100				0.2501103	
				−910				−914	
				− 3				− 5	
				0.2500187				0.2500184	
						0.2500185			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kyōto).

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VII–30	S	IV' F.o.v.	25.26	25.29	−90.7		25.34	25.40	−91.4
,,	O	,, F.u.v.	25.31	25.40	−90.6		25.36	25.47	−91.9
,,	S	,, F.u.h.	25.31	25.40	−88.0		25.38	25.48	−90.4
,,	O	,, F.o.h.	25.37	25.45	−90.1		25.41	25.51	−91.5
			25.31	25.39	−89.9		25.37	25.47	−91.3
		Länge der Scala		0.2501111				0.2501115	
		Micro-Ablesung		−899				−913	
		Red. auf 25°		− 14				− 17	
		Λ bei 25°		0.2500198				0.2500185	
		Mittel				m 0.2500192			
VII–31	N	IV F.o.v.	25.41	25.47	−98.7		25.41	25.50	−91.7
,,	S	,, F.u.v.	25.40	25.48	−99.3		25.46	25.57	−95.3
,,	N	,, F.u.h.	25.47	25.54	−94.6		25.48	25.55	−85.3
,,	S	,, F.o.h.	25.51	25.56	−92.6		25.56	25.67	−85.5
,,	N	,, F.o.h.	25.34	25.42	−92.3		25.39	25.47	−82,8
,,	O	,, F.u.h.	25.47	25.56	−97.1		25.55	25.68	−87.6
,,	N	,, F.u.v.	25.56	25.64	−94.4		25.58	25.67	−91.6
,,	O	,, F.o.v.	25.68	22.74	−94.5		25.67	25.74	−94.8
			25.48	25.55	−94.2		25.51	25.61	−89.3
				0.2501118				0.2501121	
				−942				−893	
				− 22				− 24	
				0.2500154				0.2500204	
						0.2500179			

Schneiden Combination.	Temp. red. auf.	τ_s (Sternzeit).	Λ	Mittel. τ_s / τ_m	Mittel. Λ	L′	Corrn. für elast. Biegung.
I	27.00°	1.0064505 s	1.0003402 m				
II′	”	521	466	1.0064512 s	1.0003444 m	0.9929764 m	−0.0003290 m
III′	”	513	453	1.0037032			
IV	”	507	456				
I′	27.00	1.0064343	1.0003431				
II	”	384	458	1.0064361	1.0003446	0.9930064	−0.0003290
III	”	328	449	1.0036882			
IV′	”	387	445				
I	25.00	0.5032690	0.2500187				
II′	”	683	220	0.5032671	0.2500193	0.9925477	−0.0000020
III′	”	633	186	0.5018930			
IV	”	678	179				
I′	25.00	0.5032219	0.2500200				
II	”	180	189	0.5032184	0.2500195	0.9927405	−0.0000020
III	”	171	200	0.5018444			
IV′	”	164	192				

Gleichungen für die Länge des einfachen Sekunden-pendels.

$$\left\{\begin{aligned} L &= \overset{mm}{992.6500}\left(1+\frac{\beta+\delta}{1000}+\frac{\Delta\gamma}{406.5}\right)\\ L &= 992.6800\left(1+\frac{\beta+\delta}{1000}-\frac{\Delta\gamma}{406.5}\right)\\ L &= 992.5562\left(1+\frac{\beta+\delta}{250}+\frac{\Delta\gamma}{70}\right)\\ L &= 992.7490\left(1+\frac{\beta+\delta}{250}-\frac{\Delta\gamma}{70}\right)\end{aligned}\right.$$

$$\left.\begin{aligned}\Delta\gamma &= 0.00614\\ \Delta\gamma &= 0.00680\end{aligned}\right\}\ 0.00647$$

$$\beta+\delta=0.00416$$

$$\begin{aligned}
L &= 992.6500+0.0041+0.0158=\overset{mm}{992.6699} && \overset{\mu}{-0.8}\\
L &= 992.6800+0.0041-0.0158=992.6683 && +0.8\\
L &= 992.5562+0.0165+0.0918=992.6645 && +4.6\\
L &= 992.7490+0.0165-0.0918=992.6737 && -4.6\\
 & \hphantom{=992.7490+0.0165-0.0918=}\ \overline{992.6691} &&
\end{aligned}$$

Corrn. für Mitschwingung.	L_0
m +0.0000026	0.9926500
+0.0000026	0.9926800
+0.0000105	0.9925562
+0.0000105	0.9927490

Schlussresultat.

L = 992.669 mm.
g = **979.725** cm/sec^2
g'_0 = 979.737 „ corrrigirt für die Höhe und Anziehung des Terrains.
g_0 = 979.737 „ „ „ Condensation.
γ_0 = 979.748 „

KANAZAWA.

An der nordöstlichen Ecke des Hauptgebaudes des Daishi-kōtō-gakko in Kanazawa, befindet sich ein kleiner dickmauriger feuerfester Speicher; der Pfeiler wurde in der Mitte dieses Raumes aufgebaut nach dem Plane in Tafel II. Die Temperatur des Beobachtungsraumes war ziemlich constant und frei von Luftzug oder ähnlichen Störungen.

Die Station liegt auf einer schiefen Ebene, die allmählich zur Hakusan-Kette ansteigt, welche 40*km*. südlich vom Japanischen Meere emporragt. Nicht weit vom Beobachtungsort findet sich ein altes Schloss, welches durch eine starke Steinmauer umgeschlossen ist, und in 1 *km*. Entfernung fliessen südlich der Saigawa und nordlich der Asanogawa; sonst kann man die Nachbarschaft des Beobachtungsortes als ein Terrain betrachten. Der Boden besteht aus Quaternärerde.

Die Messungsresultate sind in den folgenden Tabellen enthalten.

Station : Breite : 36° 32′,8 *N*
Länge : 9^h 6^m $39^s.5$ östlich von Greenwich.
Höhe : $26^{m.}$; $\theta=2{,}0$.
Daishi-kōtō-gakko in Kanazawa.

Datum : 8 bis 21 ten August, 1899.

Beobachter : H. Nagaoka, R. Ōtani und S. Shinjō.

Instrumente.

Chronometer : Negus 1891 für Koincidenzbeobachtung.
„ 1622 „ astronomische Beobachtung.

Durchgangsinstrument : Troughton und Simms.

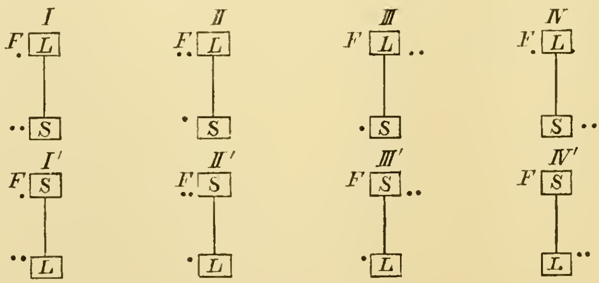
Thermometer :	Gerhardt. 4242	Gerhardt. 4243	Démichel. 3898	Démichel. 3893	Déimchel. 2586
Corrn. bei 28°	-0,07	-0,07	-0,23	-0,03	-0,23

Barometer: Aneroid; Corrn.$=-4{,}2mm$. (verglichen mit dem Normalbarometer der meteorologischen Station in Kanazawa.)

Hygrometer : Psychrometer.

Seismometer : Horizontalpendel.

Schneidencombination :

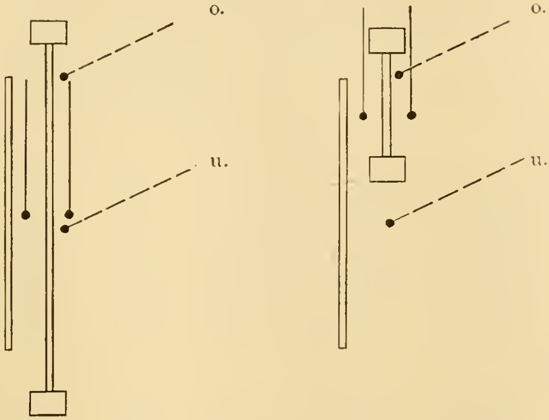


Biegungscorrection : Correction für Sekundenpendel — 329μ in L
„ „ ½S. pendel — 2μ „ „

Mitschwingungscorrection : „ „ Sekundenpendel + $4{,}0\mu$ „ „
„ „ ½S. pendel + $16{,}0\mu$ „ „

Micrometer : Oben : $100^p=99{,}42^{\mu}$ bei 28°
Unten : $100^p=99{,}93$ „ „

Lage der Thermometer:



Täglicher Gang des Chronometers 1891.

Datum		(s.z.)	ΔT.	Differenz.	Täglicher Gang.
1899-August	8	$17^{h},2$	$+50^{m}\ 15^{s},01$	$1^{s},34$	$1^{s},36$
	9	16,8	16,35	1,02	1,02
	10	16,7	17,37	1,14	1,07
	11	18,2	18,51	1,24	1,23
	12	18,3	19,75	11,71	1,47
	20	17,3	31,46	1,58	1,42
	21	20,2	33,04		

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-interval.	Temperatur. o.	Temperatur. u.	Aus-schlag in der Mitte.	Luft-druck.
				s	o	o	′	mm
VIII-9	O	I	F.o.v.	158.251	[28.61]*	28.27	23.8	756.1
,,	,,	,,	F.u.v.	158.282	[28.69]	28.46	24.0	756.2
,,	,,	,,	F.o.v.	157.965	[28.99]	28.65	25.0	755.7
,,	,,	,,	F.u.v.	158.161	[29.14]	28.82	24.2	756.5
,,	N	,,	F.u.h.	158.165	[29.28]	28.97	26.2	755.3
,,	,,	,,	F.o.h.	157.948	[29.37]	29.06	24.9	755.1
VIII-10	S	I′	F.o.v.	158.327	[28.86]	28.59	22.8	754.0
,,	,,	,,	F.u.v.	158.341	[28.87]	28.62	25.3	753.5
,,	N	,,	F.u.h.	158.270	[28.95]	28.64	25.2	753.3
,,	,,	,,	F.o.h.	158.277	[29.18]	28.68	25.3	752.6
VIII-10	O	II	F.o.v.	158.048	[30.08]	29.54	22.9	75.34
,,	,,	,,	F.u.v.	157.976	[30.01]	29.41	22.8	753.6
,, -11	N	,,	F.o.h.	158.144	[29.03]	28.68	24.9	752.0
,,	,,	,,	F.u.h.	157.999	[29.00]	28.67	26.4	752.1
,, -12	,,	,,	F.o.h.	158.261	[29.36]	29.25	24.8	754.2
,,	,,	,,	F.u.h.	158.076	[29.34]	29.24	26.0	753.8
VIII-11	S	II′	F.u.h.	158.031	[29.48]	29.35	25.0	752.2
,, -12	O	,,	F.o.h.	158.646	[29.08]	28.93	25.7	753.5
,,	,,	,,	F.o.v.	158.578	[29.09]	28.97	24.2	754.8
,,	S	,,	F.u.v.	158.106	[29.14]	29.08	25.0	754.5

* Der Quecksilberfaden dieses Thermometers wurde nachher gebrochen gefunden und nicht gebraucht für Temperaturcorrection.

SEKUNDENPENDEL. (Kanazawa.)

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 29°	T	τ'	Korrection wegen Druck-unter-schied.	τ in Stern-zeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		s
24.3	1.0063592	+158	−30	+68	1.0063788	1.0063811	0	1.0063811
23.5	579	+158	−31	+50	756			
24.5	709	+129	−33	+33	838	907	+1	908
24.7	629	+129	−31	+17	744			
24.6	627	+129	−36	+ 3	723	867	0	867
24.7	716	+129	−33	− 6	806			
								1.0063862
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
23.4	1.0063561	+119	−28	+38	1.0063690	1.0063666	+1	1.0063667
23.4	556	+119	−34	+35	676			
23.5	584	+119	−34	+33	702	706	−1	705
23.5	581	+119	−34	+30	696			
								1.0063686
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
25.4	1.0063675	+122	−28	−50	1.0063719	1.0063688	0	1.0063688
25.2	705	+122	−28	−38	761			
23.0	635	+125	−33	+30	757	715	0	715
23.0	695	+125	−37	+31	814			
21.7	588	+143	−33	−23	675	621	−1	620
21.7	664	+143	−36	−22	749			
								1.0063674
						$\left(\frac{h_2}{h_1-h_2}-0.728\right)$		
22.8	1.0063682	+134	−33	−33	1.0068750	1.0063897	+2	1.0063899
22.1	433	+143	−35	+ 7	548			
22.8	461	+143	−31	+ 3	576	884	0	884
22.3	651	+143	−33	− 7	754			
								1.0063892

SCHWINGUNGSDAUER

Datum	Beob.	Lage.	Koinc.-interval.	Stangentemp. o.	Stangentemp. u.	Ausschlag in der Mitte.	Luftdruck.
			s	°	°	′	mm
VIII–12	S	III′ F.o.v.	158.594	[30.00]	29.98	23.7	756.6
„	„	„ F.u.v.	158.178	[29.91]	29.84	25.0	757.4
„ –15	O	„ F.o.v.	158.837	[28.28]	28.28	23.2	755.6
„	„	„ F.u.v.	158 293	[28.16]	28.22	25.3	755.8
„ –13	N	„ F.u.h.	158.260	[29.36]	29.26	24.9	758.3
„	„	„ F.o.h.	158.561	[29.27]	29.23	23.7	757.6
„	O	„ „	158.605	[29.39]	29.26	24.4	759.2
„ –15	S	„ F.u.h.	158.357	[28.09]	28.04	24.7	755.0
„	„	„ F.o.h.	158.894	[28.11]	28.10	22.8	753.7
VIII–13	O	III F.o.v.	157.974	[29.50]	29.39	25.6	760.8
„	S	„ F.u.v.	157 882	[29.32]	29.29	23.7	761.1
„	N	„ F.u.h.	157.817	[29.32]	29.23	25.6	759.9
„	„	„ F.o.h.	158.035	[29.33]	29.29	24.8	760.0
VIII–14	S	IV F.o.v.	158.204	[28.33]	28.27	25.0	759.2
„	„	„ F.u.v.	158.486	[28.23]	28.21	24.6	759.7
„	O	„ F.u.h.	158.477	[28.31]	28.23	23.9	760.6
„	„	„ F.o.h.	158.058	[28.39]	28.34	24.4	760.7
VIII–19	N	IV′ F.o.v.	158.315	[28.55]	28.53	23.7	759.5
„	S	„ F.u.v.	158.250	[28.51]	28.51	25.6	759.3
„	N	„ F.u.h.	158.379	[28.65]	28.63	25.3	757.7
„	S	„ F.o.h.	158.471	[28.67]	28.65	23.2	757.9

HALBSEKUNDENPENDEL. (Kanazawa.)

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Sternzeit.	Reduction für α	Reduction auf 29°	T	τ'	Korrection wegen Druckunterschied.	τ in Sternzeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		s
24.5	1.0063454	+171	−30	−91	1.0063504	1.0063812	−1	1.0063811
24.5	622	+171	−33	−78	682			
22.2	356	+171	−29	+67	565	945	0	945
22.0	575	+171	−34	+73	785			
24.0	588	+171	−33	−24	702	793	0	793
23.8	468	+171	−30	−21	588			
24.3	450	+171	−32	−24	565			
22.2	549	+171	−32	+89	777	936	−2	934
22.6	332	+171	−28	+84	559			
								1.0063871
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
24.8	1.0063705	+171	−35	−36	1.0063805	1.0063767	0	1.0063767
24.6	743	+171	−30	−27	857			
24.1	769	+171	−35	−21	884	723	0	723
24.1	680	+171	−33	−27	791			
								1.0063745
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
22.0	1.0063611	+171	−33	+68	1.0063817	1.0063895	+1	1.0063896
22.2	498	+171	−32	+74	711			
22.5	501	+171	−30	+72	714	986	0	986
23.1	671	+171	−32	+61	871			
								1.0063941
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
23.4	1.0063566	+171	−30	+44	751	1.0063791	0	1.0063791
23.3	592	+171	−35	+46	774			
23.5	540	+171	−34	+34	711	734	0	734
23.9	504	+171	−29	+33	679			
								1.0063763

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-interval.	Stangentemp. o.	Stangentemp. u.	Ausschlag in der Mitte.	Luftdruck.
				s	°	°	′	mm
VIII-15	S	I′	F.o.v.	78.609	28.26	[28.07]	24.2	755.8
,,	,,	,,	F.u.v.	78.834	28.15	[27.89]	25.4	755.4
,, -20	,,	,,	F.o.v.	79.016	24.94	......	24.6	760.2
,,	,,	,,	F.u.v.	79.184	25.12	......	24.6	759.2
,, -16	,,	,,	F.u.h.	79.018	27.39	[27.29]	24.5	751.6
,,	,,	,,	F.o.h.	78.753	27.36	[27.20]	25.6	751.9
,, -20	N	,,	F.u.h.	79.174	25.33	[25.16]	26.6	758.3
,,	O	,,	F.o.h.	78.965	25.48	[25.32]	23.8	758.3
VIII-16	N	I	F.o.v.	78.474	27.48	[27.42]	25.4	751.9
,,	,,	,,	F.u.v.	79.000	27.43	[27.38]	26.0	752.2
,, -20	O	,,	F.o.v.	78.645	25.97	[25.65]	25.0	758.3
,,	S	,,	F.u.v.	79.122	26.12	[25.88]	25.2	758.3
,, -16	N	,,	F.u.h.	79.008	27.49	[27.38]	26.3	752.1
,,	,,	,,	F.o.h.	78.422	27.53	[27.41]	25.7	752.2
,, -20	S	,,	F.u.h.	79.127	26.25	[26.02]	24.8	758.5
,,	,,	,,	F.o.h.	78.602	26.43	[26.16]	25.3	759.2
VIII-16	S	II	F.o.v.	78.653	28.17	[28.04]	25.4	749.5
,,	,,	,,	F.u.v.	78.499	28.09	[27.89]	25.0	749.7
,, -21	,,	,,	F.o.v.	78.822	26.18	[26.00]	26.0	758.5
,,	,,	,,	F.u.v.	78.627	26.18	[25.93]	25.9	758.7
,, -17	N	,,	F.u.h.	78.429	27.63	[27.46]	25.6	751.1
,,	,,	,,	F.o.h.	78.655	27.67	[27.52]	25.8	751.5
,, -21	S	,,	F.u.h.	78.703	26.10	[25.82]	26.1	758.4
,,	O	,,	F.o.h.	79.004	26.15	[25.88]	24.4	758.9
VIII-17	N	II′	F.o.v.	79.058	27.70	[27.49]	25.2	753.8
,,	,,	,,	F.u.v.	78.577	27.55	[27.33]	25.4	752.0
,, -21	O	,,	F.o.v.	79.354	26.28	[26.05]	23.5	758.9
,,	N	,,	F.u.v.	78.717	26.39	[26.25]	25.5	758.4
,, -17	O	,,	F.u.h.	78.503	27.55	[27.39]	25.6	753.4
,,	,,	,,	F.o.h.	79.139	27.45	[27.28]	24.9	754.0
,, -21	N	,,	F.u.h.	78.698	26.41	[26.28]	25.0	758.6
,,	S	,,	F.o.h.	79.268	26.71	[26.48]	24.4	757.0
,,	,,		,,	79.260	26.51	[26.34]	25.4	757.7

HALBSEKUNDENPENDEL. (Kanazawa.)

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 28°	T	τ'	Korrection wegen Druck-unterschied.	τ in Stern-zeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		s
22.3	0.5032007	+86	−16	− 12	0.5632065	0.5031864	0	0.5031864
22.3	1915	+86	−17	− 7	1977			
20.2	1841	+83	−16	+141	2049	1873	0	1873
20.7	1773	+83	−16	+132	1972			
22.0	1840	+86	−16	+ 28	1938	1800	0	1800
21.7	1948	+86	−17	+ 29	2046			
21.6	1777	+83	−19	+123	1964	1859	0	1859
21.9	1862	+83	−15	+116	2046			
								0.5031849
						$\left(\frac{h_2}{h_1-h_2}=1.289\right)$		
22.1	0.5032062	+86	−17	+ 24	0.5032155	0.5032431	0	0.5032431
22.2	1847	+86	−18	+ 26	1941			
22.6	1992	+83	−17	+ 94	2152	2412	0	2412
22.6	1797	+83	−17	+ 87	1950			
22.3	1844	+86	−18	+ 23	1935	2484	0	2484
22.5	2084	+86	−17	+ 22	2175			
22.8	1795	+83	−16	+ 81	1943	2412	0	2412
22.9	2010	+83	−17	+ 72	2148			
								0.5032435
						$\left(\frac{h_2}{h_1-h_2}=1.288\right)$		
23.0	0.5031989	+86	−17	− 8	0.5032050	0.5031963	0	0.5031963
22.6	2052	+86	−17	− 4	2117			
21.7	1920	+83	−18	+ 84	2069	1964	0	1964
21.5	2001	+83	−18	+ 84	2150			
21.2	2082	+86	−17	+ 17	2168	1946	0	1946
21.7	1988	+86	−18	+ 15	2071			
21.2	1969	+83	−18	+ 88	2122	1838	0	1838
21.1	1846	+83	−16	+ 85	1998			
								0.5031928
						$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		
22.0	0.5031824	+86	−17	+ 14	0.5031907	0.5032370	0	0.5032370
22.1	2020	+86	−17	+ 21	2110			
21.2	1704	+83	−15	+ 79	1851	2426	0	2426
21.6	1963	+83	−17	+ 74	2103			
22.0	2050	+86	−17	+ 21	2140	2466	0	2466
21.9	1791	+86	−16	+ 25	1886			
21.7	1971	+83	−17	+ 73	2110			
22.4	1739	+83	−16	+ 60	1866	2415	0	2415
21.8	1742	+83	−17	+ 69	1877			
								0.5032419

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-interval.	Stangentemp.		Aus-schlag in der Mitte.	Luft-druck.
					o.	u.		
				s	°	°	′	mm
VIII–17	O	III′	F.o.v.	79.063	27.57	[27.43]	24.4	755.0
,,	,,	,,	F.u.v.	78.504	27.47	[27.27]	24.4	755.1
,,	,,	,,	F.u.h.	78.493	27.33	[27.21]	24.5	755.6
,,	,,	,,	F.o.h.	79.065	27.22	[27.09]	24.5	755.8
VIII–18	O	III	F.o.v.	78.822	26.06	[25.92]	24.5	758.1
,,	,,	,,	F.u.v.	78.605	25.89	[25.77]	24.4	758.1
,,	S	,,	F.u.h.	78.495	25.65	[25.52]	26.0	756.6
,,	,,	,,	F.o.h.	78.847	25.59	[25.51]	24.2	755.8
VIII–18	N	IV	F.o.v.	78.500	25.88	....	24.8	753.1
,,	,,	,,	F.u.v.	78.988	25.71	....	25.0	753.9
,,	S	,,	F.u.h.	78.987	25.41	[25.28]	25.3	756.0
,,	,,	,,	F.o.h.	78.568	25.37	[25.20]	25.2	758.6
VIII–19	S	IV′	F.o.v.	78.968	24.76	[24.53]	24.5	760.3
,,	,,	,,	F.u.v.	79.136	24.69	[24.46]	25.5	760.7
,,	,,	,,	F.u.h.	79.146	24.65	[24.47]	25.4	761.4
,,	,,	,,	F.o.h.	78.925	24.64	[24.50]	25.3	761.6

HALBSEKUNDENPENDEL. (**Kanazawa.**)

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 26°	T	τ'	Korrection wegen Druck-unterschied.	τ in Stern-zeit-sek.
mm	s				s			s
21.7	0.5031822	+86	−16	−72	0.5031820	$\left(\frac{h_2}{h_1-h_2}=1.280\right)$ 0.5032349	0	0.5032349
22.0	2050	+86	−16	−68	2052			
21.9	2055	+86	−16	−61	2064	2357	0	2357
21.6	1821	+86	−16	−56	1835			
								0.5032353
20.0	0.5031919	+86	−16	− 3	0.5031986	$\left(\frac{h_2}{h_1-h_2}=1.288\right)$ 0.5031860	0	0.5031860
20.0	2009	+86	−16	+ 5	2084			
19.8	2054	+86	−18	+16	2138	1820	0	1820
20.2	1910	+86	−16	+19	1999			
								0.5031840
20.2	0.5032052	+86	−16	+ 6	0.5032128	$\left(\frac{h_2}{h_1-h_2}=1.288\right)$ 0.5032378	0	0.5032378
20.2	1852	+86	−17	+13	1934			
20.3	1853	+86	−17	+27	1949	2345	0	2345
20.5	2024	+86	−17	+29	2122			
								0.5032362
19.6	0.5031860	+86	−16	+57	0.5031987	$\left(\frac{h_2}{h_1-h_2}=1.280\right)$ 0.5031836	0	0.5031836
19.4	1792	+86	−17	+60	1921			
19.4	1788	+86	−17	+62	1919	1802	0	1802
19.5	1878	+86	−17	+63	2010			
								0.5031819

LÄNGENMESSUNG SEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VIII-8	N	I F.o.v.	29.45	29.38	−103.2		29.41	29.34	−107.3
„	S	„ F.u.v.	.44	.41	−102.5		.35	.37	−107.5
„	N	„ F.u.h.	.36	.31	−103.7		.26	.22	−105.7
„	S	„ F.o.h.	.17	.08	−104.3		.13	.05	−109.9
			29.36	29.30	−103.4		29.29	29.25	−107.6
		Länge der Scala	1.0004882				1.0004873		
		Micro-Ablesung	−1034				−1076		
		Red. auf 29°	− 67				− 54		
		Λ 29° bei	1.0003781				1.0003743		
		Mittel				m 1.0003762			
VIII-10	S	I′ F.o.v.	29.08	29.09	−108.0		29.10	29.11	−107.8
„	N	„ F.u.v.	.21	.26	−103.2		.20	.25	−108.4
„	S	„ F.u.h.	.17	.20	−105.5		.16	.18	−107.8
„	N	„ F.o.h.	.27	.31	−105.2		.22	.27	−106.7
			29.18	29.22	−105.5		29.17	29.20	−107.7
			1.0004868				1.0004865		
			−1055				−1077		
			− 33				− 32		
			1.0003780				1.0003756		
						1.0003768			
VIII-10	S	II F.o.v.	29.54	29.57	−103.1		29.54	29.57	− 99.7
„	S	„ F.u.v.	.38	.38	− 97.1		.38	.38	−101.2
„	O	„ F.u.h.	.46	.46	−104.5		.46	.47	−104.0
„	S	„ F.o.h.	.55	.58	− 97.4		.53	.57	− 98.0
			29.48	29.50	−100.5		29.48	29.50	−100.7
			1.0004915				1.0004915		
			−1005				−1007		
			− 89				− 89		
			1.0003821				1 0003819		
						1.0003820			

LÄNGENMESSUNG SEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VIII-12	S	II′ F.o.v.	29.52	29.52	− 98.7		29.46	29.47	−102.9
„	O	„ F.u.v	.51	.51	−101.3		.48	.46	− 99.9
„	S	„ F.u.h.	.53	.52	− 98.6		.52	.52	− 99.4
„	O	„ F.o.h.	.70	.67	−100.3		.64	.62	−101.7
			29.57	29.56	− 99.7		29.53	29.52	−101.0
		Länge der Scala	1.0004926				1.0004919		
		Micro-Ablesung	− 997				−1010		
		Red. auf 29°	− 105				− 98		
		Λ bei 29°	1.0003824				1.0003811		
		Mittel				m 1.0003818			
VIII-12	N	III′ F.o.v.	29.74	29.73	− 95.6		29.69	29.71	− 97.7
„	O	„ F.u.v.	.80	.78	− 98.2		.75	.74	− 99.2
„	N	„ F.u.h.	.87	.87	−107.7		.79	.79	−108.1
„	O	„ F.o.h.	.79	.75	−101.2		.77	.73	−101.3
			29.80	29.78	−100.7		29.75	29.74	−101.6
			1.0004963				1.0004956		
			−1007				−1016		
			− 148				− 139		
			1.0003808				1.0003801		
						1.0003805			
VIII-13	S	III F.o.v.	29.36	29.33	−100.2		29.33	29.32	−104.9
„	O	„ F.u.v.	.45	.39	−101.4		.39	.33	−103.1
„	S	„ F.u.h.	.37	.37	−105.5		.28	.29	−107.7
„	O	„ F.o.h.	.38	.36	−101.3		.28	.27	−103.5
			29.39	29.36	−102.1		29.32	29.30	−104.8
			1.0004892				1.0004882		
			−1021				−1048		
			− 72				− 59		
			1.0003799				1.0003775		
						1.0003787			

LÄNGENMESSUNG SEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Beleuchtung dunkel. Temp. Scala.	Beleuchtung dunkel. Micro-abl.		Beleuchtung hell. Temp. Pendel.	Beleuchtung hell. Temp. Scala.	Beleuchtung hell. Micro-abl.
VIII-13	S	IV F.o.v.	29.03	29.03	− 96.4		29.14	29.13	−104.0
„	O	„ F.u.v.	.30	.29	−100.6		.24	.23	−101.8
„	S	„ F.u.h.	.19	.19	− 99.4		.06	.07	−104.0
„	O	„ F.o.h.	.10	.11	− 99.4		.13	.13	−100.5
			29.16	29.16	− 99.0		29.14	29.14	−102.6
		Länge der Scala		1.0004858				1.0004855	
		Micro-Ablesung		− 990				−1026	
		Red. auf 29°		− 30				− 26	
		Λ bei 29°		1.0003838				1.0003803	
		Mittel				m 1.0003821			
VIII-14	S	IV′ F.o.v.	28.82	28.83	−102.0		28.77	28.79	−104.9
„	O	„ F.u.v.	.88	.86	−100.8		.73	.73	−103.2
„	S	„ F.u.h.	.78	.78	−103.5		.72	.73	−107.1
„	O	„ F.o.h.	.80	.78	−103.7		.78	.77	−103.1
			28.82	28.81	−102.5		28.75	28.76	−104.6
				1.0004799				1.0004790	
				−1025				−1046	
				+ 33				+ 46	
				1.0003807				1.0003790	
						1.0003799			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VIII-15	N	I' F.o.v.	28.69	28.69	−92.4		28.73	28.70	−93.5
„	N	„ F.u.v.	.81	.77	−88.2		.76	.77	−84.8
„	O	„ F.u.h.	.74	.76	−86.0		.78	.83	−89.3
„	O	„ F.o.h.	.72	.71	−90.4		.72	.71	−91.7
			28.74	28.73	−89.3		28.75	28.75	−89.8
		Länge der Scala			0.2501252				0.2501253
		Micro-Ablesung			−893				−898
		Red. auf 28°			− 34				− 35
		Λ bei 28°			0.2500325				0.2500320
		Mittel				m 0.2500323			
VIII-16	S	I F.o.v.	28.12	28.09	−90.2		28.11	28.08	−94.9
„	S	„ F.u.v.	.13	.13	−85.9		.17	.18	−88.3
„	O	„ F.u.h.	.21	.17	−87.2		.20	.16	−90.2
„	O	„ F.o.h.	.20	.18	−89.8		.24	.23	−89.7
			28.17	28.14	−88.3		28.18	28.16	−90.8
					0.2501227				0.2501228
					−883				−908
					− 8				− 8
					0.2500336				0.2500312
						0.2500324			
VIII-16	S	II F.o.v.	28.18	28.18	−86.2		28.29	28.28	−87.9
„	S	„ F.u.v.	.32	.29	−85.7		.33	.32	−88.3
„	O	„ F.u.h.	.33	.30	−87.5		.37	.36	−89.6
„	O	„ F.o.h.	.40	.38	−87.7		.37	.32	−88.4
			28.31	28.29	−86.8		28.34	28.32	−88.6
					0.2501233				0.2501234
					−868				−886
					− 14				− 16
					0.2500351				0.2500332
						0.2500342			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VIII–17	S	II′ F.o.v.	27.52	27.50	−86.9		27.58	27.58	−89.7
,,	N	,, F.u.v.	.64	.63	−85.8		.62	.61	−89.3
,,	S	,, F.u.h.	.56	.54	−84.7		.61	.58	−83.3
,,	N	,, F.o.h.	.56	.66	−89.3		.65	.67	−88.4
			27.60	27.58	−86.7		27.62	27.61	−87.7
		Länge der Scala	0.2501203				0.2501205		
		Micro-Ablesung	−867				−877		
		Red. auf 28°	+ 19				+ 18		
		Λ bei 28°	0.2500355				0.2500346		
		Mittel				m 0.2500351			
VIII–17	O	III′ F.o.v.	27.45	27.43	−87.6		27.52	27.52	−88.9
,,	O	,, F.u.v.	.55	.54	−88.4		.55	.57	−88.6
,,	S	,, F.u.h.	.57	.54	−84.2		.64	.64	−85.9
,,	S	,, F.o.h.	.73	.74	−82.8		.71	.74	−88.1
			27.58	27.56	−85.8		27.61	27.62	−87.9
		Lange der Scala	0.2501202				0.2501205		
		Micro-Ablesung	−858				−879		
		Red. auf 26°	− 73				− 74		
		Λ bei 26°	0.2500271				0.2500252		
		Mittel				0.2500262			
VIII–18	N	III F.o.v.	25.84	25.84	−93.4		25.85	25.87	−93.3
,,	N	,, F.u.v.	.88	.88	−89.6		.89	.88	−88.9
,,	N	,, F.u.h.	.94	.89	−89.7		.92	.92	−89.1
,,	N	,, F.o.h.	.98	.99	−87.8		.95	.98	−91.4
			25.91	25.90	−90.1		25.90	25.91	−90.7
			0.2501133				0.2501133		
			−901				−907		
			+ 4				+ 5		
			0.2500236				0.2500231		
						0.2500234			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Kanazawa.)

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VIII-18	S	IV F.o.v.	25.93°	25.93°	−89.3 μ		25.99°	52.98°	−91.5 μ
,,	S	,, F.u.v.	.99	.98	−89.2		.96	.98	−94.6
,,	O	,, F.u.h.	.98	.98	−88.1		.96	.98	−88.7
,,	O	,, F.o.h.	.87	.38	−88.6		.88	.90	−89.8
			25.94	25.94	−88.8		25.95	25.96	−91.2
		Länge der Scala		0.2501134				0.2501135	
		Micro-Ablesung		−888				−912	
		Red. auf 26°		+ 3				+ 2	
		Λ bei 26°		0.2500249				0.2500225	
		Mittel				0.2500237 m			
VIII-19	N	IV′ F.o.v.	25.16	25.15	−92.4		25.14	25.14	−93.0
,,	N	,, F.u.v.	.13	.12	−91.7		.18	.17	−92.4
,,	O	,, F.u.h.	.22	.21	−88.9		.25	.26	−90.9
,,	O	,, F.o.h.	.30	.22	−88.8		.30	.27	−88.5
			25.20	25.18	−90.5		25.22	25.21	−91.2
				0.2501103				0.2501104	
				−905				−912	
				+ 37				+ 36	
				0.2500235				0.2500228	
						0.2500232			

Schneiden Combination.	Temp. red. auf	τ_s (Sternzeit)	Λ	Mittel. τ_s / τ_m	Mittel. Λ	L′	Corrn. für elast. Biegung.
I	29°.00	1ˢ.0063862	1ᵐ.0003762				
II′	,,	892	818	1ˢ.0063892	1ᵐ.0003802	0ᵐ.9931341	−0ᵐ.0003290
III′	,,	871	805	1.0036413			
IV	,,	941	821				
I′	29.00	1.0063686	1.0003768				
II	,,	674	820	1.0063717	1.0003794	0.9931680	−0.0003290
III	,,	745	787	1.0036239			
IV′	,,	763	799				
I	28.00	0.5032435	0.2500324				
II′	,,	419	351	0.5032392	0.2500294	0.9926975	−0.0000020
III′	26.00	353	262	0.5018652			
IV	,,	362	237				
I′	28.00	0.5031849	0.2500323				
II	,,	928	342	0.5031859	0.2500283	0.9929034	−0.0000020
III	26.00	840	234	0.5018121			
IV′	,,	819	232				

Gleichungen für die Länge des einfachen Sekundenpendels.

$$\left\{\begin{aligned} L &= \overset{mm}{992.8091}\left(1+\frac{\beta+\delta}{1000}+\frac{\Delta\gamma}{406.5}\right)\\ L &= 992.8430\left(1+\frac{\beta+\delta}{1000}-\frac{\Delta\gamma}{406.5}\right)\\ L &= 992.7115\left(1+\frac{\beta+\delta}{250}+\frac{\Delta\gamma}{70}\right)\\ L &= 992.9174\left(1+\frac{\beta+\delta}{250}-\frac{\Delta\gamma}{70}\right)\end{aligned}\right.$$

$$\left.\begin{aligned}\Delta\gamma &= 0.00694\\ \Delta\gamma &= 0.00726\end{aligned}\right\}0.00710$$

$$\beta+\delta = 0.00390$$

$$\begin{array}{lr} L = 992.8091 + 0.0039 + 0.0173 = 992.8303 & \overset{\mu}{-0.3} \\ L = 992.8430 + 0.0037 - 0.0173 = 992.8296 & +0.4 \\ L = 992.7115 + 0.0155 + 0.1007 = 992.8277 & +2.3 \\ L = 992.9174 + 0.0155 - 0.1007 = 992.8322 & -2.2 \\ \hline \ 992.8300 & \end{array}$$

Corrn. für Mitschw.	L_0
m +0.0000040	m 0.9928091
+0.0000040	0.9928430
+0.0000160	0.9927115
+0.0000160	0.9929174

$L = 992.830$ mm.
$g = \mathbf{979.834}$ cm/sec²
$g_0' = 979.890$ „ corrigirt für die Höhe und Anziehung des Terrains.
$g_0 = 979.875$ „ „ „ „ Condensation.
$\gamma_0 = 979.878$ „

TŌKYŌ.

Die Pendel wurden in Central-süd-ost-keller (Tafel II) des physikalischen Instituts der Universität geschwungen. Der Granitpfeiler, den wir in Kyōto gebraucht haben, wurde hier wieder aufgebaut, und darauf die Pendel geschwungen. Der Keller hat sich sehr gut gegen die Temperaturschwankungen gehalten, da wir die Eingangsthür zugeschlossen und von Aussen die Koincidenzbeobachtung gemacht haben.

Das Institut ist auf einem Boden gebaut, welcher nicht sehr fest ist; deswegen hat man grosse Sorgfalt gegenüber den Erdbeben anzuwenden. Das Erdbeben in Alaska hat den Boden in langsame aber grosse Bewegung versetzt, wovon die Koincidenzbeobachtung und das Erdbebendiagram genaue Kenntniss giebt. Die Störungen in g topographischen Ursprungs werden sehr gering sein im Vergleich zu Kyōto oder Kanazawa, da die Stadt Tōkyō auf einer sehr weiten Ebene gebaut ist.

Die folgenden Tabellen enthalten die Messungsresultate :—

Station : { Breite : 35° 42′,6 N.
Länge : 9^h 19^m 3^s östlich von Greenwich.
Höhe : 15^m : $\theta=2,0$ }

Physikalisches Institut der Universität zu Tōkyō.

Datum : 9 bis 16ten September, 1899.

Beobachter : H. Nagaoka, R. Ōtani und S. Shinjō.

Instrumente.

Chronometer : { Negus No. 1891 für Koincidenzbeobachtung.
„ „ 1622 „ astronomische Beobachtung. }

Durchgangsinstrument : Kübel.

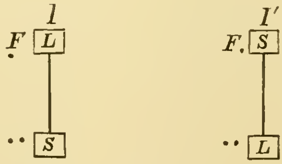
		Gerhardt	Gerhardt
Thermometer :		4242	4243
	Corrn. bei 20°	−0,08	−0,08

Barometer : Aneroid Casella No. 2452 : richtig.

Hygrometer : Psychrometer.

Seismometer : Horizontalpendel.

Schneidencombination des Pendels :

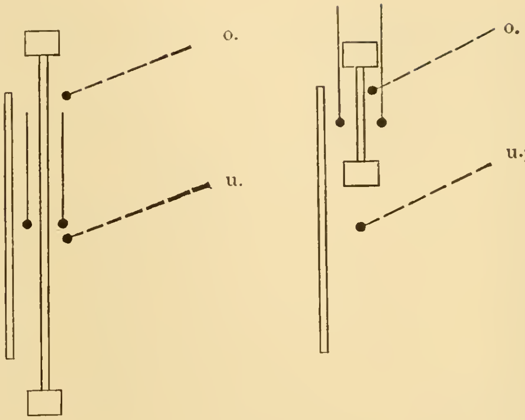


Biegungscorrection :	Correction für Sekundenpendel	-329μ	in L
	„ „ ½S. pendel	$-\ \ 2\mu$	„ „
Mitschwingungscorrection :	„ „ Sekundenpendel	$3,4\mu$	„ L
	„ „ ½S. pendel	$13,4\mu$	„ „

Micrometer : Oben : $100^p=100,^\mu 91$ bei 22°

Unten : $100^p=100,^\mu 46$ „ „

Lage der Thermometer :



Täglicher Gang des Chronometers 1891.

Datum (S.Z.)		ΔT	Differenz.	Mittlerer täglicher Gang.
1899-September-9	$21^{h},9$	$1^{h}\ 3^{m}\ 35^{s},18$	$1^{s},44$	$1^{s},63$
10	17,9	36,62	1,74	1,76
11	18,2	38,36	2,05	1,96
12	18,4	40,41	1,81	1,77
13	19,0	42,22	1,33	1,30
14	19,4	43,55	3,49	1,83
16	18,8	47,04		

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.	Koinc.-intervall.	Stangentemp.			Ausschlag in der Mitte.	Luftdruck.
				o.	u.	$\frac{(o)+3(u)}{4}$		
			s	°	°	°	′	mm
IX-10	N	I F.o.v.	158.794	22.15	22.11	22.12	19.1	756.0
,,	,,	,, F.u.v.	158.925	21.98	21.93	21.94	19.0	756.8
,, -11	S	,, F.u.v.	159.295	21.51	21.52	21.52	17.5	754.2
,,	,,	,, F.o.v.	158.875	21.60	21.62	21.62	19.0	754.0
,, -10	O	,, F.u.h.	158.895	21.89	21.78	21.81	18.8	757.1
,,	,,	,, F.o.h.	158.701	21.85	21.82	21.83	19.4	757.2
,, -11	N	,, F.o.h.	158.955	21.68	21.62	21.64	19.0	754.5
,,	S	,, F.u.h.	159.245	21.62	21.60	21.60	19.2	755.1
IX-12	N	I′ F.o.v.	159.311	21.32	21.29	21.30	18.0	754.4
,,	,,	,, F.u.v.	159.244	21.31	21.30	21.30	19.1	754.7
,,	,,	,, F.u.v.	159.098	21.36	21.37	21.37	19.0	753.8
,,	,,	,, F.o.v.	159.106	21.36	21.34	21.34	17.6	754.4
,,	O	,, F.u.h.	159.221	21.38	21.34	21.35	19.0	754.8
,,	,,	,, F.o.h.	159.084	21.38	21.31	21.33	17.9	753.8
,,	S	,, F.o.h.	159.110	21.19	21.24	21.23	18.5	753.8
,,	,,	,, F.u.h.	159.152	21.25	21.29	21.28	19.0	753.6

SEKUNDENPENDEL. (Tōkyō).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction			T	τ'	Korrection wegen Druck-unterschied.	τ in Stern-zeit-sek.
		auf Stern-zeit.	für α	auf 22°				
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
mm	s				s			s
18.8	1.0063374	+190	−19	−11	1.0063534	1.0063561	+1	1.0063562
18.8	320	+190	−19	+6	497			
18.3	173	+205	−16	+45	407	676	0	676
18.4	341	+205	−19	+35	562			
18.2	332	+190	−19	+18	521	653	0	653
18.3	411	+190	−20	+16	597			
18.3	308	+205	−19	+34	528	611	+1	612
18.2	193	+205	−20	+37	415			
								1.0063626
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
17.8	1.0063167	+228	−17	+65	1.0063413	1.0063484	0	1.0063484
18.1	193	+228	−19	+65	467			
17.8	252	+228	−19	+59	520	518	+1	519
17.7	249	+228	−16	+61	522			
17.9	203	+228	−19	+60	472	430	−1	429
17.5	257	+228	−17	+62	530			
17.8	247	+228	−18	+72	529	489	0	489
17 8	230	+228	−19	+67	506			
								1.0063430

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-intervall.	Stangentemp. o.	Stangentemp. u.	Stangentemp. $\frac{4(o)+(u)}{5}$	Aus-schlag in der Mitte.	Luft-druck.
IX-14	S	I	F.o.v.	$78\overset{s}{.}733$	$21\overset{\circ}{.}34$	$21\overset{\circ}{.}27$	$21\overset{\circ}{.}33$	$18\overset{\prime}{.}8$	762.9 mm
„	„	„	F.u.v.	79.219	21.27	21.21	21.26	20.4	762.5
„	N	„	F.u.v.	79.202	21.33	21.31	21.33	20.5	761.0
„	„	„	F.o.v.	78.633	21.32	21.28	21.31	19.2	761.0
„	„	„	F.u.h.	79.247	21.35	21.32	21.34	20.5	761.5
„	„	„	F.o.h.	78.641	21.33	21.31	21.33	18.8	761.0
„	„	„	F.o.h.	78.629	21.32	21.32	21.32	18.8	761.2
„	„	„	F.u.h.	79.199	21.32	21.30	21.32	20.6	761.0
IX-13	N	I′	F.o.v.	79.092	21.41	21.29	21.39	20.5	756.9
„	„	„	F.u.v.	79.152	21.33	21.31	21.33	19.3	756.9
„	„	„	F.u.v.	78.997	21.34	21.33	21.34	19.2	759.0
„	„	„	F.o.v.	79.052	21.43	21.39	21.42	21.0	758.4
„	S	„	F.u.h.	79.125	21.37	21.29	21.35	19.3	757.0
„	N	„	F.o.h.	79.040	21.45	21.40	21.44	21.0	757.1
„ -14	O	„	F.o.h.	79.033	21.15	21.12	21.14	21.0	762.8
„	„	„	F.u.h.	79.238	21.03	21.01	21.03	19.4	762.9

HALBSEKUNDENPENDEL. (Tōkyō).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	Reduction für α	Reduction auf 22°	T	τ'	Korrection wegen Druck-unter-schied.	τ in Stern-zeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=1.289\right)$		s
17.9	0.5031956	+76	−9	+31	0.5032054	0.5032308	0	0.5032308
17.9	758	+76	−11	+34	1857			
18.0	765	+76	−11	+31	1861	397	0	397
18.0	997	+76	−10	+32	2095			
18.0	747	+76	−11	+30	1842	414	0	414
18.0	994	+76	−9	+31	2092			
18.0	999	+76	−9	+31	2097	400	0	400
17.9	766	+76	−11	+31	1862			
						$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		**0.5032380**
17.4	0.5031810	+103	−11	+28	0.5031930	0.5031882	0	0.5031882
17.4	785	+103	−10	+31	1909			
17.9	849	+103	−10	+30	1972	2008	0	2008
17.8	826	+103	−12	+27	1944			
17.7	796	+103	−10	+30	1919	1882	0	1882
17.6	831	+103	−12	+26	1948			
17.4	834	+76	−12	+40	1938	1765	0	1765
17.4	751	+76	−10	+45	1862			**0.5031884**

LÄNGENMESSUNG SEKUNDENPENDEL. (Tōkyō).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Beleuchtung dunkel. Temp. Scala.	Beleuchtung dunkel. Micro-abl.		Beleuchtung hell. Temp. Pendel.	Beleuchtung hell. Temp. Scala.	Beleuchtung hell. Micro-abl.
			°	°	μ		°	°	μ
IX–10	S	I F.o v.	21.93	22.03	−115.7		21.87	22.00	−116.5
„	O	„ F.u.v.	22.01	22.07	−115.1		21.91	22.02	−117.0
„	S	„ F.u.h.	22.04	22.15	−117.5		21.92	22.08	−120.2
„	O	„ F.o.h.	22.17	22.26	−115.6		22.10	22.22	−117.1
			22.04	22.13	−116.0		21.95	22.08	−117.7
		Länge der Scala	1.0003676				1.0003667		
		Micro-Ablesung	−1160				−1177		
		Red. auf 22°	−7				+9		
		Λ bei 22°	1.0002509				1.0002499		
		Mittel.				m 1.0002504			
IX–13	S	I′ F.o.v.	21.03	21.11	−117.8		20.96	21.06	−118.6
„	O	„ F.u.v.	21.12	21.20	−119.2		21.08	21.16	−119.2
„	S	„ F.u.h.	21.21	21.25	−117.2		21.07	21.17	−121.4
„	O	„ F.o.h.	21.24	21.28	−117.1		21.20	21.29	−117.5
			21.15	21.21	−117.8		21.08	21.16	−119.2
			1.0003521				1.0003513		
			−1178				−1192		
			+157				+170		
			1.0002500				1.0002491		
						1.0002496			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Tōkyō).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Scala.	Micro-abl.		Beleuchtung hell. Temp. Pendel.	Scala.	Micro-abl.
			°	°	μ		°	°	μ
IX-15	N	I F.o.v.	21.46	21.42	−89.8		21.50	21.48	−94.0
„	„	„ F.u.v.	21 65	21.67	−90.1		21.64	21.69	−93.2
„	O	„ F.u.h.	21.74	21.82	−89.9		21.78	21.86	−92.5
„	„	„ F.o.h.	21.83	21.88	−91.2		21.87	21.97	−92.0
			21.67	21.70	−90.3		21.70	21.75	−92.9
		Länge der Scala		0.2500956				0.2500959	
		Micro-Ablesung		−903				−929	
		Red. auf 22°		+ 15				+ 14	
		Λ bei 22°		0.2500068				0.2500044	
		Mittel.				m 0.2500056			
IX-13	S	I′ F.o.v.	21.62	21.72	−91.1		21.61	21.74	−94.4
„	O	„ F.u.v.	21.66	21.79	−89.0		21.67	21.84	−94.8
„	S	„ F.u.h.	21.62	21.82	−84.0		21.61	21.81	−93.4
„	O	„ F.o h.	21.61	21.81	−88.1		21.64	21.82	−90.3
			21.63	21.79	−88.0		21.63	21.80	−93.2
				0.2500960				0.2500961	
				−880				−932	
				+ 17				+ 17	
				0.2500097				0.2500046	
						0.2500071			

Schneiden Combination.	Temp. red. auf	τ_s / τ_m	Λ	L′	Corrn. für elast. Biegung.	Corrn. für Mitschwingung.	L_0
I	22°.00	s 1.0063625 1.0036149	m 1.0002504	m 0.9930577	m −0.0003290	m +0.0000034	m 0.9927321
I′	22.00	1.0063480 1.0036003	1.0002496	0.9930859	−0.0003290	+0.0000034	0.9927603
I	22.00	0.5032380 0.5018640	0.2500056	0.9926074	−0.0000020	+0.0000134	0.9926188
I′	22.00	0.5031884 0.5018145	0.2500071	0.9928098	−0.0000020	+0.0000134	0.9928212

Gleichungen für die Länge des einfachen Sekundenpendels.

$$\left\{\begin{aligned} L&=\overset{\mathrm{mm}}{992.7321}\left(1+\frac{\beta+\delta}{1000}+\frac{\Delta\gamma}{406.5}\right)\\ L&=992.7603\left(1+\frac{\beta+\delta}{1000}-\frac{\Delta\gamma}{406.5}\right)\\ L&=992.6188\left(1+\frac{\beta+\delta}{250}+\frac{\Delta\gamma}{70}\right)\\ L&=992.8212\left(1+\frac{\beta+\delta}{250}-\frac{\Delta\gamma}{70}\right)\end{aligned}\right.$$

$$\left.\begin{aligned}\Delta\gamma&=0.00577\\ \Delta\gamma&=0.00714\end{aligned}\right\}0.00645$$

$$\beta+\delta=0.00880$$

L = 992.7321 + 0.0087 + 0.0158 =	992.7566	μ −1.7
L = 992.7603 + 0.0087 − 0.0158 =	992.7532	+1.7
L = 992.6188 + 0.0349 + 0.0916 =	992.7453	+9.6
L = 992.8212 + 0.0349 − 0.0916 =	992.7645	−9.6
	992.7549	

L = 992.755 mm.

g = **979.810** cm/sec²

g_0' = 979.813 „ corrigirt für die Höhe und Anziehung des Terrains.

g_0 = 979.791 „ „ „ Condensation.

γ_0 = 979.806 „

MIZUSAWA.

Als Beobachtungsraum (Tafel II) wurde ein Keller der internationalen Breitenstation benutzt. Er liegt 130*m*. nördlich des Breitenbeobachtungsraumes. Statt des Pfeilers wurde das Mauerstativ verwendet, welches zum Zweck der Schwerkraftsbestimmung, beim Erbauen des Gebäudes, an der Westwand des Kellers errichtet worden war. Der Beobachtungsraum war ziemlich eng und daher leidet er etwas an Temperaturschwankungen, im Vergleich mit den anderen Stationen. Ferner war die Luftfeuchtigkeit immer ziemlich gross, sodass man den Unterschied in den beiden Psychrometerthermometern selten bemerkt hat. Es ist daher zu befürchten dass die Oberfläche des Pendels während der Beobachtung mit einem Wasserniederschlag bedeckt war.

Für genaue Beschreibung des Beobachtungsortes verweisen wir auf den ausführlichen Bericht in den Verhandlungen der zwölften internationalen geodätischen Conferenz.

In den Folgenden finden sich die Messungsresultate in tabellarischer Form dargestellt.

Station: Breite : 39° 8′ 7″ N.
Länge : 9^h 24^m 30^s östlich von Greenwich.
Höhe : 60*m.* ; $\theta=2{,}5$

Keller der Breitenstation zu Mizusawa.

Datum : 13 bis 27ten Juli, 1900.

Beobachter : S. Shinjō und R. Ōtani.

Instrumente.

Chronometer : Negus No. 1891 für Koincidenzbeobachtung.
„ „ 1622 „ astronomische Beobachtung.
„ „ 1888 „ Vergleichung mit Chronograph.

Durchgangsinstrument : Troughton und Simms.

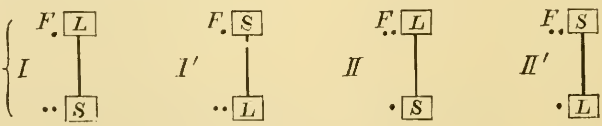
		Gerhardt 4243	Démichel 1425	Démichel 1426
Thermometer :	Corrn. bei 17°	−0,07	−0,28	−0,41
	„ 18°	−0,08	−0,30	−0,40
	„ 19°	−0,08	−0,31	−0,38
	„ 20°	−0,08	−0,31	−0,38
	„ 21°	−0,08	−0,32	−0,39
	„ 22°	−0,08	−0,35	−0,40

Barometer : Aneroid Casella No. 2452 ; Corrn. −1,9mm.

Hygrometer : Psychrometer der Breitenstation.

Seismometer : Horizontalpendel.

Schneidencombination des Pendels :



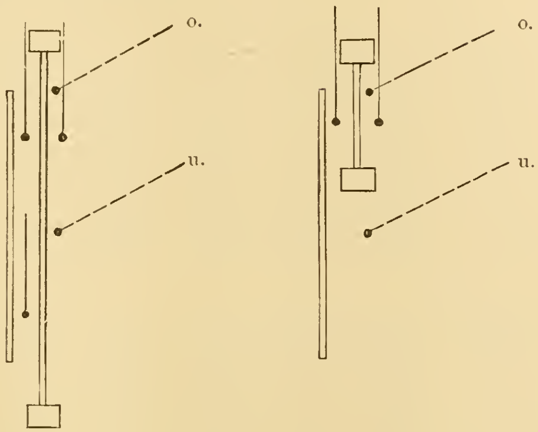
L bedeutet leichtes Gewicht.
S „ schweres „

Biegungscorrection :	Correction für Sekundenpendel	-329μ	in L
	„ „ ½S. pendel	$-\ 2\mu$	„ „
Mitschwingungscorrection :	„ „ Sekundenpendel	$+\ 0{,}4\mu$	„ „
	„ „ ½S. pendel	$+\ 1{,}5\mu$	„ „

Micrometer: Oben : $100^{p} = 100{,}57^{\mu}$ bei 21°

Unten : $100^{p} = 100{,}63^{\mu}$ „ „

Lage der Thermometer:



Täglicher Gang des Chronometers. No. 1891.

Datum (S.Z.)			⊿ T	Differenz.	Mittlerer täglicher Gang.
1900-Juli-13	16^{h}	$49{,}0^{m}$	$+16{,}40^{s}$		
				$5{,}58^{s}$	$1{,}84^{s}$
16	17	20,0	21,98		
				1,58	1,63
17	16	22,0	23,56		
				7,47	1,86
21	16	43,0	31,03		
				7,07	1,41
26	17	0,0	38,10		
				0,76	0,79
27	16	6,5	38,86		

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-intervall.	Stangentemp. o.	u.	$\frac{(o)+3(u)}{4}$	Ausschlag in der Mitte.	Luftdruck.
				s	°	°	°	′	mm
VII–14	S	I	F.o.v.	164.261	19.09	19.05	19.06	19.4	748.5
„	S	„	F.u.v.	164.636	18.96	18.84	18.87	17.9	748.5
„	O	„	F.u.h.	164.709	19.09	18.83	18.90	17.9	748.9
„	O	„	F.o.h.	164.288	19.08	18.82	18.89	18.7	749.3
„ –15	S	„	F.o.h.	164.582	18.21	18.07	18.11	18.6	747.4
„	S	„	F.u.h.	164.908	18.56	18.42	18.46	17.9	746.8
„	O	„	F.u.v.	164.893	18.70	18.42	18.49	17.9	746.8
„	O	„	F.o.v.	164.452	18.82	18.46	18.55	18.6	746.4
VII–17	S	I′	F.o.v.	164.978	17.77	17.66	17.69	18.1	748.0
„	S	„	F.u.v.	164.966	17.60	17.49	17.52	18.9	748.1
„	O	„	F.u.h.	164.897	17.90	17.67	17.73	18.5	748.6
„	O	„	F.o.h.	164.976	17.90	17.73	17.77	17.9	748.5
VII–27	O	„	F.o.v.	164.311	19.91	19.57	19.66	17.9	751.1
„	O	„	F.u.v.	164.229	20.16	19.65	19.78	18.7	751.7
„	S	„	F.u.h.	164.217	20.12	19.67	19.78	18.9	751.5
„	S	„	F.o.h.	164.253	20.28	19.85	19.96	17.5	751.1
VII–18	O	II′	F.o.v.	165.593	17.14	17.03	17.06	17.9	749.7
„	O	„	F.u.v.	165.087	17.36	17.19	17.23	18.9	749.4
„	S	„	F.u.h.	164.887	17.64	17.49	17.53	19.2	748.5
„	S	„	F.o.h.	165.363	17.60	17.40	17.45	17.8	747.6
„	O	„	F.o.h.	165.290	17.64	17.39	17.45	17.8	747.3
„	O	„	F.u.h.	164.791	17.62	17.40	17.46	18.9	746.2
„	S	„	F.u.v.	164.823	17.50	17.40	17.43	18.9	745.1
„	S	„	F.o.v.	165.213	17.56	17.45	17.48	17.7	745.1
VII–19	S	II	F.o.v.	164.829	17.47	17.37	17.40	18.9	750.6
„	S	„	F.u.v.	164.833	17.44	17.32	17.35	18.3	751.4
„	O	„	F.u.h.	164.750	17.55	17.30	17.36	18.1	752.4
„	O	„	F.o.h.	164.936	17.50	17.28	17.34	19.3	753.1
„ –20	S	„	F.o.h.	165.154	16.66	16.51	16.55	18.8	751.7
„	S	„	F.u.h.	164.908	16.95	16.85	16.88	18.9	751.5
„	O	„	F.u.v.	164.855	17.15	16.94	16.99	18.3	750.6
„	O	„	F.o.v.	164.929	17.17	16.98	17.03	18.9	749.6

SEKUNDENPENDEL. (Mizusawa).

Dunstdruck	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Stern-zeit.	für α	auf 19°	T	τ'	Korrection wegen Druck-unter-schied.	τ in Stern-zeit-sek.
mm	s				s	$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		s
16.3	1.0061252	+214	−20	−6	1.0061440	1.0061527	0	1.0061527
16.4	112	+214	−17	+12	321			
16.2	084	+214	−17	+9	290	562	−1	561
16.4	242	+214	−19	+10	447			
16.1	131	+214	−18	+83	410	522	−1	521
16.0	010	+214	−17	+50	257			
16.4	015	+214	−17	+48	260	534	+1	535
16.4	180	+214	−18	+42	418			
								1.0061536
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
14.6	1.0060984	+190	−17	+122	1.0061279	1.0061310	0	1.0061310
14.6	0988	+190	−19	+138	297			
14.6	1014	+190	−18	+118	304	327	0	327
14.5	0985	+190	−17	+114	272			
17.0	1233	+92	−17	−61	247	275	−1	274
16.8	1263	+92	−19	−73	263			
16.9	1268	+92	−19	−73	268	287	−1	286
17.6	1255	+92	−16	−89	242			
				(17°)				**1.0061299**
						$\left(\frac{h_2}{h_1-h_2}=0.728\right)$		
13 9	1.0060756	+217	−17	−6	1.0060950	1.0061244	0	1.0061244
14.1	0943	+217	−19	−21	1120			
14.4	1017	+217	−20	−49	1165	286	−1	285
14.3	0841	+217	−17	−42	0999			
14.3	0868	+217	−17	−42	1026	342	+2	344
14.2	1054	+217	−19	−43	1209			
14.3	1042	+217	−19	−40	1200	308	0	308
14.2	0897	+217	−17	−45	1052			
								1.0061295
						$\left(\frac{h_2}{h_1-h_2}=0.733\right)$		
14.2	1.0061037	+217	−19	−37	1.0061200	1.0061197	+1	1.0061198
14.2	1038	+217	−18	−33	1204			
14.2	1069	+217	−17	−34	1235	114	−1	113
14.2	1000	+217	−20	−32	1165			
13.6	0918	+217	−19	+42	1158	114	0	114
13.9	1010	+217	−19	+11	1219			
14.1	1030	+217	−18	+1	1230	173	+1	174
14.0	1002	+217	−19	−3	1197			
								1.0061150

SCHWINGUNGSDAUER

Datum.	Beob.	Lage.		Koinc.-intervall.	Stangentemp. o.	Stangentemp. u.	Stangentemp. $\frac{4(o)+(u)}{5}$	Aus-schlag in der Mitte.	Luft-druck.
				s	°	°	°	′	mm
VII-21	S	I	F.o.v.	81.588	17.49	17.35	17.46	18.4	748.9
,,	S	,,	F.u.v.	82.345	17.55	17.40	17.52	19.1	749.1
,,	O	,,	F.u.h.	82.341	17.65	17.32	17.58	19.8	749.4
,,	O	,,	F.o.h.	81.637	17.92	17.51	17.84	19.1	750.1
,,	S	,,	F.o.h.	81.662	17.90	17.60	17.84	19.2	750.1
,,	S	,,	F.u.h.	82.282	17.80	17.50	17.74	19.1	750.8
,, -22	O	,,	F.u.v.	82.378	17.05	16.87	17.01	19.7	752.8
,,	O	,,	F.o.v.	81.787	17.29	17.03	17.24	18.9	752.6
VII-22	S	I′	F.o.v.	81.883	18.82	18.30	18.72	21.0	750.2
,,	S	,,	F.u.v.	82.020	18.63	18.21	18.55	18.7	750.0
,,	O	,,	F.u.h.	81.972	18.59	18.13	18.50	18.7	750.3
,,	O	,,	F.o.h..	81.946	18.56	18.11	18.47	20.2	750.1
,, -23	S	,,	F.o.h.	82.009	17.80	17.61	17.76	21.2	749.0
,,	S	,,	F.u.h.	82.092	17.98	17.70	17.92	19.1	749.1
,,	O	,,	F.u.v.	82.081	18.30	17.89	18.22	18.9	749.5
,,	O	,,	F.o.v.	81.936	18.54	18.21	18.47	20.0	749.5
VII-24	O	II′	F.o.v.	82.373	18.52	18.22	18.46	20.5	750.6
,,	O	,,	F.u.v.	81.623	18.64	18.29	18.57	18.9	750.5
,,	S	,,	F.u.h.	81.628	18.64	18.39	18.59	19.1	750.3
,,	S	,,	F.o.h.	82.283	18.82	18.54	18.76	19.7	749.9
,,	O	,,	F.o.h.	82.304	18.93	18.48	18.84	20.1	749.9
,,	O	,,	F.u.h.	81.605	19.00	18.53	18.91	19.1	749.5
,,	S	,,	F.u.v.	81.599	18.99	18.68	18.93	18.9	749.5
,,	S	,,	F.o.v.	82.363	19.14	18.73	19.06	18.7	750.1
VII-25	S	II	F.o.v.	81.598	19.72	19.23	19.62	18.9	747.2
,,	S	,,	F.u.v.	81.448	19.57	19.08	19.47	20.2	747.0
,,	O	,,	F.u.h.	81.405	19.49	18.99	19.39	20.2	747.4
,,	O	,,	F.o.h.	81.642	19.44	19.08	19.37	19.3	747.5
,, -26	S	,,	F.o.h.	81.783	18.81	18.55	18 76	18.9	747.9
,,	S	,,	F.u.h.	81.509	19.07	18.77	19.01	19.9	748.1
,,	O	,,	F.u.v.	81.503	19.40	18.91	19.30	20.5	748.1
,,	O	,,	F.o.v.	81.740	19.59	19.08	19.49	18.9	748.0

HALBSEKUNDENPENDEL. (Mizusawa).

Dunstdruck.	Schwingungsdauer in Uhrzeit-sek.	Reduction auf Sternzeit.	Reduction für α	Reduction auf 18°	T	τ'	Korrection wegen Druckunterschied.	τ in Sternzeit-sek.
						$\left(\frac{h_2}{h_1-h_2}=1.290\right)$		
mm 14.2	s 0.5030831	+95	−9	+25	s 0.5030942	0.5031315	0	s 0.5031315
14.2	546	+95	−10	+22	653			
14.3	548	+95	−10	+19	652	231	0	231
14.4	813	+95	−10	+7	905			
14.8	803	+95	−10	+7	895	191	0	191
14.7	569	+95	−10	+12	666			
14.0	534	+95	−10	+46	665	151	0	151
14.2	756	+95	−9	+35	877			
								0.5031222
						$\left(\frac{h_2}{h_1-h_2}=1.280\right)$		
15.2	0.5030719	+82	−12	−33	0.5030756	0.5030665	0	0.5030665
15.3	668	+82	−9	−25	716			
15.0	686	+82	−9	−23	736	724	0	724
15.1	696	+82	−11	−22	745			
15.0	672	+82	−12	+11	753	669	0	669
15.0	640	+82	−10	+4	716			
15.0	645	+82	−9	−10	708	657	0	657
15.1	699	+82	−11	−22	748			
								0.5030679
				(19°)		$\left(\frac{h_2}{h_1-h_2}=1.279\right)$		
15.3	0.5030536	+82	−11	+25	0.5030632	0.5031268	0	0.5031268
15.4	818	+82	−9	+20	911			
15.7	816	+82	−10	+19	907	233	0	233
15.8	569	+82	−10	+11	652			
15.7	561	+82	−11	+7	639	236	0	236
15.7	825	+82	−10	+4	901			
15.9	827	+82	−9	+3	903	279	0	279
15.9	539	+82	−9	−3	609			
								0.5031254
						$\left(\frac{h_2}{h_1-h_2}=1.289\right)$		
16.4	0.5030846	+82	−9	−29	0.5030890	0.5030833	0	0.5030833
16.4	885	+82	−11	−22	934			
16.0	901	+82	−11	−18	954	753	0	753
16.0	811	+82	−10	−17	866			
16.1	758	+82	−9	+11	842	725	0	725
16.1	861	+82	−10	−0	933			
16.2	863	+82	−11	−14	920	698	0	698
16.2	773	+82	−9	−23	823			
								0.5030752

LÄNGENMESSUNG SEKUNDENPENDEL. (Mizusawa).

Datum.	Beob.	Lage.		Beleuchtung dunkel. Temp. Pendel.	Scala.	Micro-abl.		Beleuchtung hell. Temp. Pendel.	Scala.	Micro-abl.
VII-13	S	I	F.o.v.	19.73	19.77	−121.3		19.76	19.83	−115.6
„	O	„	F.o.h.	19.89	19.93	−117.0		19.89	19.87	−119.9
„	O	„	F.u.h.	19.95	19.96	−117.9		19.89	19.94	−116.9
„	S	„	F.u.v.	19.99	19.97	−113.2		19.90	19.92	−117.6
VII-15	O	„	F.o.v.	19.00	19.05	−119.4		19.29	19.35	−115.7
„	S	„	F.o.h.	19.46	19.49	−111.2		19.46	19.48	−118.7
„	O	„	F.u.h.	19.69	19.75	−118.6		19.56	19.62	−117.2
„	S	„	F.u.v.	19.74	19.78	−116.4		19.56	19.62	−119.1
				19.68	19.71	−116.9		19.66	19.70	−117.6
		Länge der Scala			1.0003270				1.0003268	
		Micro-Ablesung			−1169				−1176	
		Red. auf 19°			−126				−122	
		Λ bei 19°			1.0001975				1.0001970	
		Mittel.					m 1.0001973			
VII-15	S	I′	F.o.v.	19.13	19.16	−119.1		19.38	19.44	−118.6
„	O	„	F.o.h.	19.54	19.61	−109.0		19.56	19.59	−110.3
„	S	„	F.u.h.	19.65	19.73	−114.9		19.63	19.69	−125.0
„	O	„	F.u.v.	19.67	19.70	−113.9		19.60	19.62	−114.4
VII-17	O	„	F.o.v.	18.27	18.32	−115.0		18.46	18.52	−113.1
„	O	„	F.o.h.	18.62	18.70	−111.3		18.59	18.66	−115.4
„	S	„	F.u.h.	18.81	18.82	−113.2		18.74	18.78	−117.0
„	S	„	F.u.v.	18.95	18.98	−117.0		18.83	18.89	−118.8
				19.08	19.13	−114.2		19.10	19.15	−116.6
					1.0003173				1.0003176	
					−1142				−1166	
					−15				−18	
					1.0002016				1.0001992	
							1.0002004			

LÄNGENMESSUNG SEKUNDENPENDEL. (Mizusawa).

Datum.	Beob.	Lage.	Beleuchtung dunkel. Temp. Pendel.	Temp. Scala.	Micro-abl.		Beleuchtung hell. Temp. Pendel.	Temp. Scala.	Micro-abl.
VII–17	S	II′ F.o.v.	18.63	18.67	−100.9		18.69	18.71	−106.7
„	S	„ F.o.h.	19.02	19.04	−117.8		18.92	18.93	−123.9
„	O	„ F.u.h.	19.09	19.14	−114.6		18.92	18.95	−114.3
„	O	„ F.u.v.	19.05	19.10	−118.4		18.93	18.97	−118.7
VII–19	O	„ F.o.v.	17.61	17.62	−123.8		17.53	17.56	−123.3
„	S	„ F.o.h.	17.53	17.57	−117.4		17.51	17.54	−124.9
„	S	„ F.u.h.	17.44	17.52	−128.6		17.43	17.49	−123.0
„	O	„ F.u.v.	17.60	17.64	−120.9		17.55	17.61	−123.9
			18.25	18.29	−117.8		18.19	18.22	−119.8
		Länge der Scala		1.0003032				1.0003020	
		Micro-Ablesung		−1178				−1198	
		Red. auf 17°		− 231				− 220	
		Λ bei 17°		1.0001623				1.0001602	
		Mittel.				m 1.0001613			
VII–19	S	II F.o.v.	17.60	17.62	−118.9		17.59	17.62	−121.4
„	S	„ F.o.h.	17.74	17.75	−115.6		17.72	17.73	−115.8
„	O	„ F.u.h.	17.83	17.86	−116.0		17.75	17.81	−117.1
„	O	„ F.u.v.	17.79	17.83	−125.1		17.77	17.81	−121.4
VII–20	O	„ F.o.v.	17.15	17.16	−126.9		17.39	17.44	−123.1
„	O	„ F.o.h.	17.57	17.73	−131.6		17.62	17.69	−122.1
„	S	„ F.u.h.	17.85	17.90	−119.2		17.80	17.83	−117.1
„	S	„ F.u.v.	18.00	18.06	−124.4		17.89	17.95	−122.8
			17.69	17.74	−122.2		17.69	17.74	−120.5
				1.0002940				1.0002940	
				−1222				−1205	
				− 128				− 128	
				1.0001590				1.0001607	
						1.0001599			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Mizusawa).

Datum.	Beob.	Lage.		Beleuchtung dunkel.				Beleuchtung hell.		
				Temp.		Micro-abl.		Temp.		Micro-abl.
				Pendel.	Scala.			Pendel.	Scala.	
VII-20	O	I	F.o.v.	18.30	18.32	−92.0		18.47	18.47	−93.5
„	O	„	F.o.h.	18.44	18.45	−90.1		18.53	18.54	−91.5
„	S	„	F.u.h.	18.35	18.36	−90.4		18.48	18.53	−87.7
„	S	„	F.u.v.	18.31	18.33	−86.7		18.50	18.54	−90.6
VII-22	S	„	F.o.v.	18.16	18.13	−90.0		18.36	18.32	−89.3
„	S	„	F.o.h.	18.36	18.34	−89.4		18.52	18.52	−86.5
„	O	„	F.u.h.	18.50	18.53	−92.6		18.63	18.67	−89.1
„	O	„	F.u.v.	18.50	18.50	−92.6		18.69	18.68	−91.2
				18.37	18.37	−90.5		18.52	18.53	−89.9
		Länge der Scala			0.2500817				0.2500824	
		Micro-Ablesung			−905				−899	
		Red. auf 18°			− 17				− 24	
		Λ bei 18°			0.2499895				0.2499901	
		Mittel.					m 0.2499398			
VII-22	S	I′	F.o.v.	18.57	18.54	−89.5		18.86	18.82	−88.0
„	S	„	F.o.h.	18.91	18.90	−86 3		19.11	19.11	−84.7
„	O	„	F.u.h.	19.06	19.08	−88.0		19.31	19.32	−89.9
„	O	„	F.u.v.	19.11	19.11	−88.9		19.35	19.32	−90.1
VII-23	O	„	F.o.v.	19.16	19.13	−92.0		19.58	19.52	−90.8
„	O	„	F.o.h.	19.72	19.68	−92.9		19.96	19.93	−91.6
„	S	„	F.u.h.	19.74	19.72	−90.9		19.98	19.92	−89.4
„	S	„	F.u.v.	19.91	19.90	−94.7		20.16	20.11	−93.4
				19.27	19.26	−90.4		19.54	19.51	−89.7
					0.2500854				0.2500865	
					−904				−897	
					− 59				− 71	
					0.2499891				0.2499897	
							0.2499894			

LÄNGENMESSUNG HALBSEKUNDENPENDEL. (Mizusawa).

Datum.	Beob.	Lage.	Beleuchtung dunkel.				Beleuchtung hell.		
			Temp.		Micro-abl.		Temp.		Micro-abl.
			Pendel.	Scala.			Pendel.	Scala.	
VII-23	O	II' F.o.v.	19.60	19.59	−90.8		19.92	19.88	−91.4
„	O	„ F.o.h.	19.91	19.91	−89.7		20.14	20.13	−90.2
„	S	„ F.u.h.	19.95	19.94	−87.5		20.21	20.18	−87.1
„	S	„ F.u.v.	19.90	19.90	−90.6		20.11	20.11	−89.0
VII-25	S	„ F.o.v.	19.55	19.52	−93.9		19.68	19.65	−93.9
„	S	„ F.o.h.	19.66	19.71	−90.6		19.85	19.92	−89.7
„	O	„ F.u.h.	19.87	19.91	−86.7		20.06	20.07	−88.8
„	O	„ F.u.v.	19.91	19.92	−88.7		20.09	20.10	−89.3
			19.79	19.80	−89.8		20.01	20.01	−89.9
		Länge der Scala		0.2500877				0.2500886	
		Micro-Ablesung		−898				−899	
		Red. auf 19°		− 37				− 47	
		Λ bei 19°		0.2499942				0.2499940	
		Mittel.				m 0.2499941			
VII-25	S	II F.o.v.	19.67	19.62	−85.9		19.96	19.93	−85.0
„	S	„ F.o.h.	19.77	19.74	−93.4		19.99	19.97	−92.3
„	O	„ F.u.h.	20.03	20.03	−89.5		20.20	20.19	−91.5
„	O	„ F.u.v.	20.09	20.11	−90.7		20.29	20.30	−91.8
VII-26	O	„ F.o.v.	20.45	20.40	−88.3		20.74	20.71	−89.7
„	O	„ F.o.h.	20.57	20.61	−88.7		20.81	20.84	−90.1
„	S	„ F.u.h.	20.72	20.71	−85.2		20.96	20.93	−88.2
„	S	„ F.u.v.	20.89	20.91	−89.7		21.09	21.11	−87.4
			20.27	20.27	−88.9		20.51	20.50	−89.5
				0.2500897				0.2500906	
				−889				−895	
				− 59				− 70	
				0.2499949				0.2499941	
						0.2499945			

Schneiden Combination.	Temp. red. auf	τ_s	Λ	Mittel. $\frac{\tau_s}{\tau_m}$	Mittel. Λ	L′	Corrn. für elast. Biegung.
	°	s	m	s	m	m	m
I	19.00	1.0061536	1.0001973	1.0061416	1.0001793	0.9934236	−0.0003290
II′	17.00	295	1613	1.0033945			
I′	19.00	10.061299	1.0002004	1.0061225	1.0001802	0.9934620	−0.0003290
II	17.00	150	1599	1.0033755			
I	18.00	0.5031222	0.2499898	0.5031238	0.2499920	0.9930043	−0.0000020
II′	19.00	254	941	0.5017501			
I′	18.00	0.5030679	0.2499894	0.5030716	0.2499920	0.9932105	−0.0000020
II	19.00	752	945	0.5016980			

Gleichungen für die Länge des einfachen Sekunden-pendels.

$$\left\{\begin{aligned} L &= \overset{\text{mm}}{993.0950}\left(1+\frac{\beta+\delta}{1000}+\frac{\Delta\gamma}{406.5}\right) \\ L &= 993.1334\left(1+\frac{\beta+\delta}{1000}-\frac{\Delta\gamma}{406.5}\right) \\ L &= 993.0038\left(1+\frac{\beta+\delta}{250}+\frac{\Delta\gamma}{70}\right) \\ L &= 993.2100\left(1+\frac{\beta+\delta}{250}-\frac{\Delta\gamma}{70}\right) \end{aligned}\right.$$

$$\left.\begin{aligned} \Delta\gamma &= 0.00786 \\ \Delta\gamma &= 0.00727 \end{aligned}\right\} 0.00756$$

$$\beta+\delta = 0.00245$$

$$\begin{aligned} L &= 993.0950+0.0024+0.0185 = 993.1159 & \overset{\mu}{+0.7} \\ L &= 993.1334+0.0024-0.0185 = 993.1173 & -0.7 \\ L &= 993.0038+0.0097+0.1073 = 993.1208 & -4.2 \\ L &= 993.2100+0.0097-0.1073 = 993.1124 & +4.2 \\ & \overline{\quad\quad 993.1166} & \end{aligned}$$

L = 993.117 mm.

g = 980.167 cm/sec²

g_0' = 980.179 „ corrigirt für die Höhe und Anziehung des Terrains

g_0 = 980.179 „ „ „ Condensation.

γ_0 = 980.105 „

Corrn. für Mitschwingung.	L_0
m +0.0000004	m 0.9930950
+0.0000004	0.9931334
+0.0000015	0.9930038
+0.0000015	0.9932100

Schlussbemerkung.

Der Uebersicht halber stellen wir die Resultate der vier Bestimmungen zusammen, mit den nach der Helmert'schen Formel

$$\gamma_0 = 978{,}046\{1 + 0{,}005302\ sin^2\varphi - 0{,}000007\ sin^2\ 2\varphi\}$$

berechneten Werte.

	$g\left(\frac{cm}{sec^2}\right)$	g'_0	Mit Condensations-correction (g_0)	γ_0	$\gamma_0 - g_0$
Kyōto	979,725	979,737	979,737	979,748	+11
Kanazawa	979,884	979,890	979,875	979,878	+ 3
Tōkyō	979,810	979,813	979,791	979,806	+15
Mizusawa	980,167	980,179	980,179	980,105	−74

Hieraus erhellt dass die Schwerebeschleunigung, mit Ausnahme von Mizusawa, sehr nahe dem normalen Wert steht. Die Uebereinstimmung ist am vollkommensten in Kanazawa ; Kyōto liegt am weitesten vom Stillen Ocean oder vom Japanischen Meere, und kann daher als auf dem Festland gelegen betrachtet werden. Mizusawa ist, gleichwie Kyōto, ziemlich tief innen gelegen, aber die Ursache der Abweichung scheint hauptsächlich im geotectonischen Character der Gegend zu liegen. Die Untersuchung der störenden Schicht wird am bequemsten durch die relativen Messungen der Schwerkraft jener Gegend zu führen sein.

Inzwischen haben wir vier Halbsekundenpendel, die von Stückrath angefertigt sind, für den Zweck der Anschlussmessung, erhalten. Die Anschlussmessung des g mit Potsdam ergab für Tōkyō den Wert

$$g = 979{,}814 \frac{cm}{sec^2}$$

an demselben Ort, wo wir die reversiblen Pendel geschwungen haben, wenn

$$g\ (Potsdam) = 981{,}290 \frac{cm}{sec^2}$$

angenommen wird.

Weitere Anschlüsse von Kyōto und Mizusawa mit Tōkyō gaben folgende Resultate

$$g\ (Ky\bar{o}to) = 979{,}734 \frac{cm}{sec^2}$$

$$g\ (Mizusawa) = 980{,}186 \frac{cm}{sec^2}$$

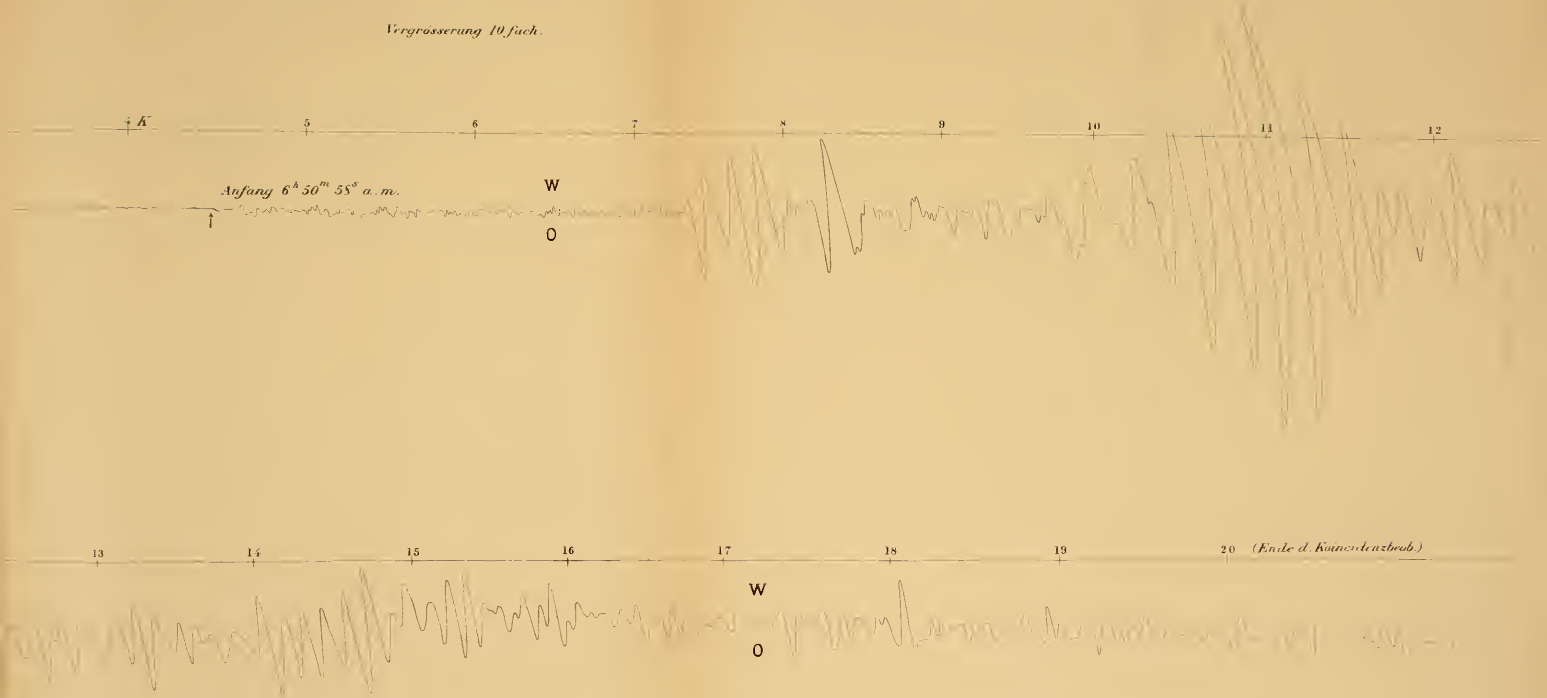
Diese relativen Messungen stimmen ziemlich gut mit den absoluten überein. Könnten wir die Biegungsconstante für das Sekundenpendel noch genauer ermitteln, so würde der absoluten Messung viel mehr Gewicht beizulegen sein; aber der Unterschied zwischen den absoluten und relativen Messungen ist ziemlich klein, sodass der Fehler innerhalb der Unsicherheit in der Biegungscorrection liegt. Wenn es möglich wäre, auf irgend eine einfache Weise, die Biegungscorrection genau zu bestimmen, so würde es nicht viel Mühe kosten, unsere Resultate nochmals zu revidiren.

Obgleich wir über die letzte Stelle der Schwerebeschleunigung nicht sicher sind, so unterliegt es doch noch keinem Zweifel dass die früher ermittelten Werte der Schwerkraft in Tōkyō etwas mit Fehlern behaftet waren. Wie wir aus den noch nicht veröffentlichten Resultaten der an zehn Stationen in die mittleren Breite 35° N. vorgenommen Messungen vorhersagen können, besitzt die Schwerkraft in Japan, wie in den oben genannten drei Stationen, keinen eigenthümlichen Character wie in anderen Ländern. Mit dem Fortschreiten der relativen Messungen wird es möglich sein klares Licht in dieses Untersuchungsgebiet zu werfen.

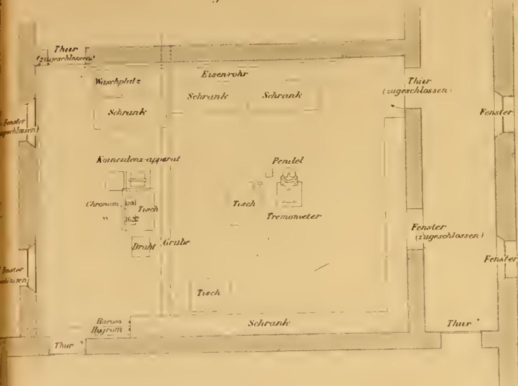
Zum Schluss sei es uns gestattet den Herren Rector Kinoshita, Prof. Muraoka und Prof. Mizuno, der Universität zu Kyōtō

Herren Rector Hōjō und Prof. Noda des Daishi-kōtō-gakko; Herrn Director Kimura der internationalen Breitenstation zu Mizusawa, für die freundliche Unterstützung womit diese Herren unsere Messungen erleichtert haben, unseren aufrichtigsten Dank auszusprechen.

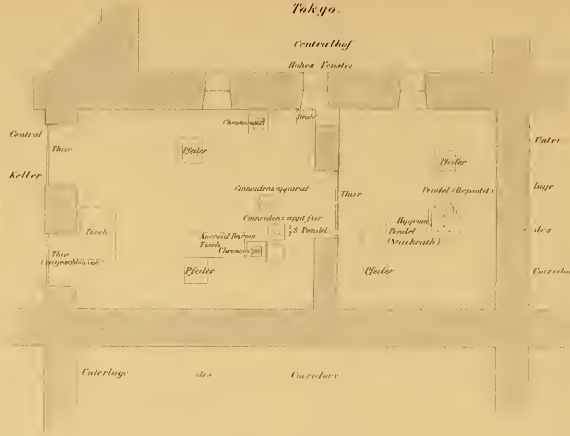
Vergrösserung 10 fach.



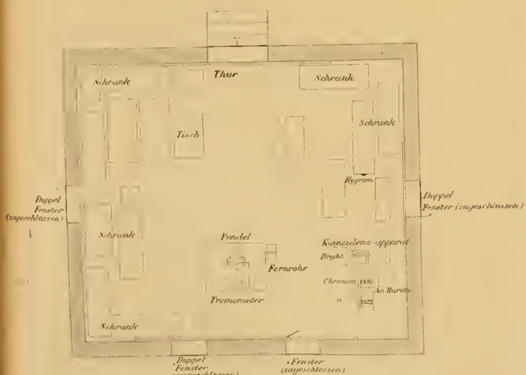
Kyoto.



Tokyo.



Kanazawa.



Mizusawa.

ERRATA.

P. 2, line 2, read ‘Chladni's’ for ‘Chladui's’.
P. 2, line 17, read ‘trace’ for ‘have’.
P. 3, line 1, read ‘flexure’ for ‘pressure’.
P. 3. line 17, omit ‘increase in the’.
P. 4, line 17, read ‘with’ for ‘within’.
P. 4, line 24, read ‘the , for ‘then’.
P. 5, tables, in $\frac{T}{\triangle T.}$ ‘—’ is not the sign of division.
P. 9, line 12, read ‘these’ for ‘three’.
P. 10, line 17, read ‘then’ for ‘there’.
P. 11, line 16, insert after ‘5’. *‘Change of elasticity in soft iron.’*
P. 12, line 2, read ‘about’ for ‘adout’.
P. 13, line 12, insert after ‘depression’ ‘and the modulus of elasticity’.
P. 13, table , read ‘$T+\frac{5}{8}W$’ for ‘$T\times\frac{5}{8}W$’.
P. 14, line 5, read ‘compare’ for ‘conform’.
P. 15, table , read ‘$T+\frac{5}{8}W$’ for ‘$T+\frac{8}{5}W$’.
P. 16, line 3, read ‘less steep’ for ‘much steeper’.
P. 18, table , read ‘—4’ for ‘—3’.

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Change of the Modulus of Elasticity in Ferromagnetic Substances by Magnetization.

By

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S. Shimizu, *Rigakushi*,

and

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With 1 Plate.

1. It has been generally admitted that magnetization has very little effect upon the elasticity of ferromagnetic substances. Wertheim[1] measured with a micrometer the elongation of an iron wire due to tension in the magnetized and unmagnetized states and obtained exactly the same results. Guillemin[2] placed an iron bar horizontally, fixing it at one end, while from the other, which was left free, he hung a small weight. The magnetization of the bar by a co-axial coil produced a slight raising of the weight. Since there is an attraction between the bar and the coil, when magnetized, the above effect may not be totally due to the increase of the elasticity of the bar; but to ascribe the effect wholly to the attraction, as G.

1) Wertheim, Ann. de Chim. et de Phys. (3) **12**, 610, 1842.
2) Guillemin, Comp. Rend. **22**, 264 and 432, 1846.

Wiedemann[1] did does not seem to be justifiable. Wartmann[2] used Chladui's figure to investigate the change of elasticity of magnetized iron and steel plates, and also examined the sound accompanying longitudinal and transversal vibrations of magnetized iron wires. No influence of magnetization was observed. Trèves[3] put in vibration two tuning forks having the same period of vibration. When one of them was put in a coil and magnetized by a strong electric current, its vibration was accelerated producing the beat; but when the current was broken, the beats were no longer audible and the two notes were in unison. This shows an increace of elasticity by magnetization. H. Tomlinson[4] found that the elongation of an iron wire by loading is independent of magnetization. Bock[5] found the effect to be less than $\frac{1}{2}$%, if there was any. By passing an electric current through a stretched pianoforte wire, M.G. Noyes[6] noticed an increase of elasticity, which was less than 1%. But in his later experiment[7], he did not accept the conclusion, to which he was led by his former experiment. We can, however, have from his tables an increase of elasticity; but he attributed it to the effect of temperature. Maurain[8] also found a small increase of frequency in a tuning fork placed in a very strong magnetic field. In the investigation of the effect of tension upon the magnetic elongation of a pianoforte wire, B. Brackett[9] observed that the effect of tension was to diminish the magnetic elongation, and he ascribed it to an increase of elasticity. J. S.

1) Wiedemann's Electricität III. 813.
2) Wartmann, Ann. de Chim. et de Phys. **24**, 360, 1848.
3) Trèves, Comp. Rend. **67**, 321, 1868; Archives des soc nat. N. S. **33**, 74, 1868.
4) Tomlinson, Proc. Roy Soc. **40**, 447, 1886.
5) Bock, Wied. Ann. **54**, 442, 1895; Phil. Mag. (5) **39**, 548, 1895.
6) Noyes, Phy. Rev. (4) **2**, 277, 1895.
7) Noyes, Phy. Rev. (6) **3**, 432, 1896.
8) Maurain, Comp. Rend. **121**, 248, 1895.
9) Brackett, Phy. Rev. (5) **5**, 257, 1897.

Stevens and H. G. Dorsey[1] used the method of pressure and applied the interference fringes to measure the amount of depression. The effect of magnetization upon a loaded iron or steel bar was found to be very small; it showed a minute increase of elasticity, amounting only to $\frac{1}{300}\%$ for the strongest current used. The effect also increased with magnetizing current. In the next year, Stevens measured the magnetic elongation of steel wires under different tensions, and ascribed the change of elongation to that of elasticity by magnetization, as Brackett did. The result was an increase nearly proportional to the magnetizing force. Lately K. Tangl[2] has published his results on the same subject. He made use of the principle that the moment of a bifilar suspension increases with tension applied to its lower end. By magnetizing the wire under constant tension, he measured the amount of the magnetic elongation. The tension was, then, so varied that the wire returned to its initial length. The ratio of the tension so varied to the magnetic elongation was taken as proportional to the increase in the modulus of elasticity in that field. Besides iron, he also examined nickel wires which showed a small increase of elasticity. In fields ranging from 200 to 480 C. G. S. units, the maximum increase amounted to about 1.02% for iron as well as for nickel. He also investigated the effect of tension, but the result does not seem to be satisfactory.

All of these experiments show that the magnetization increases slightly the modulus of elasticity of iron and nickel, and that the change increases with the magnetizing force, but its law is not clearly brought out.

2. Different methods, by which previous experimenters determined the said effect may be grouped under three heads. The first

1) Stevens and Dorsey, Phy. Rev. (2) **9**, 116, 1899; Phy. Rev. (2) **11**, 95, 1900; Phy. Zeitschr. **2**, 682, 1900.

2) Tangl, Ann. der Phys. **6**, 34, 1901.

method makes use of the acoustic phenomena and can not be used for accurate determinations.

The second is the method of elongation. Since, the elongation due to the change of elasticity is only a small fraction of the total elongation, this method is only suitable for the accurate measurement of the effect in question, when a differential method is applicable. Unfortunately this is not the case in the present instance ; for if we first stretch the wire by a tension and then magnetize it, there is always magnetic elongation which is far greater than that due to the change of elasticity.

We may, however, modify the measurement in the following way, as Bidwell and others have done. The wire is first brought under tension, and then the magnetic elongation in different fields is determined. This process is repeated with several loadings. From these sets of observation, we may decide the question.—How is the elasticity of a ferromagnetic wire affected by magnetization ?

Let E′ and E be the modulii of elasticity within and without the magnetizing field, and e′ and e the magnetic elongations per unit of length with and without the tension, respectively. We first load the wire with the tension T per square centimeters, and then magnetize it; the total elongation in 1cm will be

$$\frac{\mathrm{T}}{\mathrm{E}}+e'\left(1+\frac{\mathrm{T}}{\mathrm{E}}\right).$$

Next, changing the order of operations, we first magnetize the wire and then stretch it ; then elongation will be

$$e+(1+e)\frac{\mathrm{T}}{\mathrm{E}}.$$

If the elongation is independent of the order of operations, we get, neglecting small quantities,

$$\frac{\mathrm{E}'-\mathrm{E}}{\mathrm{E}'\mathrm{E}}=\frac{(e'-e)}{\mathrm{T}};$$

putting $\mathrm{E}'-\mathrm{E}=\delta\mathrm{E}$, we have

$$\frac{\delta E}{E}=\frac{(e-e')E}{T-(e-e')E}.$$

If we wish to compare two curves corresponding to the tensions T and $T+\Delta T$, the above equation becomes

$$\frac{\delta E}{E}=\frac{\Delta e.E}{\Delta T-\Delta e.E},$$

where Δe is the difference of magnetic elongations corresponding to the tensions T and $T+\Delta T$.

In the preceding paper, two of us studied the effect of tension on magnetic elongation for iron, Wolfram steel, nickel, and nickel steel From these results, we calculated the change of elasticity, as shown in the following tables : —

Soft iron

$\frac{T}{\Delta T}$	$\frac{167\text{gr.}}{660}$	$\frac{2145\text{gr.}}{659}$	$\frac{4125\text{gr.}}{1320}$
H	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$
30	2.24×10^{-2}	0.83×10^{-2}	0.59×10^{-2}
80	2.23	0.98	0.71
300	3.22	1.43	0.67

Wolfram steel

$\frac{T}{\Delta T}$	$\frac{4430\text{gr.}}{3540}$	$\frac{7965\text{gr.}}{7070}$	$\frac{15030}{10600}$
H	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$
100	0.10×10^{-2}	0.21×10^{-2}	0.14×10^{-2}
300	0.18	0.28	0.24
500	0.28	0.31	2.27

Nickel

$\frac{T}{\Delta T}$	$\frac{863\text{gr.}}{688}$	$\frac{2239\text{gr.}}{688}$	$\frac{4304\text{gr.}}{1376}$
H	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$
10	-3.85×10^{-2}	-1.45×10^{-2}	-0.44×10^{-2}
20	-5.93	-6.33	-1.36
60	-1.46	-7.98	-8.77
120	$+3.14$	-2.54	-7.53
260	$+6.90$	$+1.97$	-1.93

Nickel steel (45 % Ni)

$\frac{T}{\Delta T}$	$\frac{156\text{gr.}}{307}$	$\frac{770\text{gr.}}{601}$	$\frac{3842\text{gr.}}{1230}$
H	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$	$\frac{\delta E}{E}$
50	14.10×10^{-2}	4.58×10^{-2}	2.00×10^{-2}
100	14.90	5.60	2.50
150	15,00	6.80	2.40
300	15.00	7.13	2.57
500	15.00	6.45	2 53

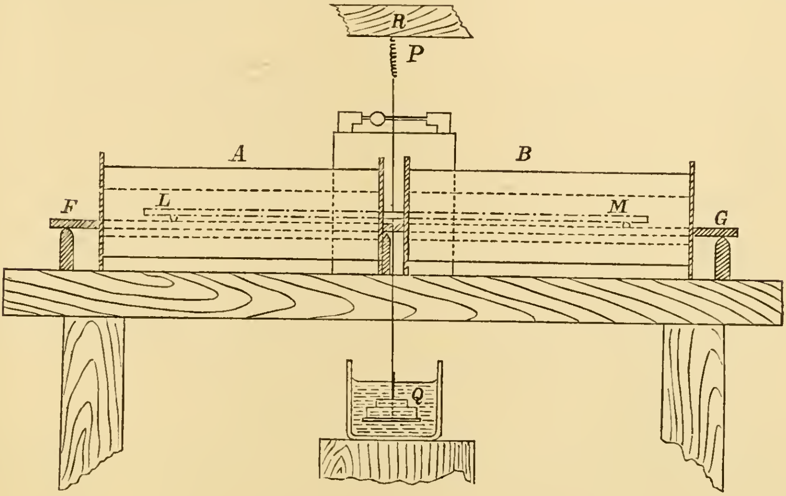
Here H denotes the external field and T the tension per square millimeters. The calculation of $\frac{\delta E}{E}$ from Steven's results for a piano-forte wire gives 1.9×10^{-2} in a field of 40 C.G.S. units, which approximately agrees with the results for soft iron.

From these tables, we see that in iron and nickel steel, the magnetization considerably increases the modulus of elasticity, the amount of the change for a given load increasing with the magnetizing field. The increase also varies with tension ; it decreases as the tension is increased. Wolfram steel shows a small increase of elasticity ; under a constant field, the increase reaches a maximum as the tension is increased. In nickel, the elasticity decreases in the weak fields and increases in the strong. The change is also a function of the tension ; in weak fields, the diminution reaches a maximum and then gradually decreases as the tension is increased. In strong fields, the increase becomes less and less and at last changes its sign with the increase of tension. The field in which the change of elasticity vanishes becomes greater as the tension is increased.

The third is the method of flexure. The advantage of this method lies in the fact that the differential effect can be measured, by suspending a weight at the middle of a ferromagnetic bar and then measuring the change of depression caused by magnetizing it. Such a bar elongates or contracts by magnetizition, while its thickness diminishes or increases ; but as we shall soon indicate, the lateral elongation or contraction will be very small compared with the change of depression due to that of elasticity.

Hence, of these three methods, that of flexure is the most suitable for studying the change of elasticity. We therefore used this method to investigate the said effect and also to test the results of the elongation method just referred to.

3. Our method of measurement was similar to that of Stevens and Dorsey, as shown in the annexed figure.



A and B were two magnetizing coils of the same dimensions, which rested horizontally in a co-axial line. FG was a stout brass rod of rectangular section extending between two fulcrums ; it was also supported at the midde point by another fulcrum. The coils can, therefore, be moved independently of the bar. LM was a rod to be tested placed in the axial line of the coils. It was supported at L and M by two fulcrums ; one of them was an ordinary wedge fixed to the brass rod, while the other consisted of a cylinder, which could rotate about its own axis. Q was the weight suspended from the middle of the bar. At the center of the bar, a fine copper wire, the diameter of which was about 0.08mm, was soldered and stretched vertically upwards by means of a weak spring P. This wire was wound once round a rotating cylinder, to which a small mirror was attached, and then stretched upwards, as used in Hertz's dynamometer.*

* Hertz, Instrumentenkunde, 3, 17, 1883 ; Gesammelte Werke Ba. 1.

The rotation of the cylinder was observed by means of a vertical scale and a telescope.

The dimensions of each part of our arrangement were as follows :—

Length of each coil	= 39.90 cm,
Its internal diameter	= 5.80 cm,
$4\pi n$	= 393.5,
Distance between the coils in air gap	= 2.5 cm for iron and steel, = 2.0 cm for nickel and cobalt,
Distance between two fulcrums L and M	= 59.91 cm for iron and steel, = 21.59 cm for nickel and cobalt,
Diameter of the rotating cylinder	= 0.172 cm,
Scale distance	= 261.3 cm.

The sensibility of our apparatus was such that the displacement of one division of the image of the vertical scale in the field of the telescope corresponded to a change of depression of 1.72×10^{-5}cm in the middle of our ferromagnetic rod. It was neccessary to protect the mirror and the thin copper wire from air currents in order to prevent minute vibrations of the mirror.

The measurements were conducted in the following order. The bar to be tested was placed in the axial line of the coils and then loaded by a weight. The tension of the fine copper wire was then suitably adjusted by means of a screw fixed to the support R, and the mirror was directed towards the telescope. This adjustment was effected as in the experiment described in the preceding paper. To begin with, a current through the coils was made or broken and the working of the arrangement tested. The bar was then demagnetized and the initial reading taken. A current was then passed through the coils and the corresponding deflection noted. These processes were repeated with successively increasing currents.

Since the resistance of the coils did not exceed 30 ohms, no heating of the core due to current was observed during the time, in which the deflection was taken ; hence we dispensed with water-jacketing arrangement.

The lateral contraction or elongation due to magnetization was at most of the order 2×10^{-6} cm for iron and 7×10^{-6} cm for nickel. For, the maximum elongation or contraction per centimeter in the field strength used in the present experiment was about 4×10^{-6} and 27×10^{-9} cm for iron and nickel respectively. Hence, assuming the change of volume to be negligibly small compared with that of length, the maximum lateral contraction or elongation was approximately 2×10^{-6} and 7×10^{-6} cm for the three metals respectively. But in our experiments, the displacement of 1mm of the vertical scale in the field of the telescope corresponds to a change of depression of 1.72×10^{-5} cm. Thus the lateral change of dimensions due to magnetization is within the limit of experimental errors. The disturbance of the results due to magnetic elongation or contraction in the longitudinal direction was eliminated by means of the rotating cylinder, which served as one of fulcrums.

The bar bent slightly downwards if loaded ; hence when it was magnetized, it would strive to make itself straight. This may cause an apparent increase of elasticity ; but it was confirmed by a direct experiment that the effect was negligibly small. For, the reading obtained by inclining the two coils with respect to the bar to a degree greatr than the actual case was almost the same as in the case when the coils rested in a coaxial line.

Since the bar was considerably shorter than the whole length of the coils, it lay nearly in a uniform field, except at the middle. The effect of the air gap between the coil was also studied, varying its

width by 1 or 2 cm ; however, such a change had no sensible effect on our results.

4. The dimensions of our specimens and their modulii of elasticity are given in the following table :—

Metal	Soft iron	Steel	Wolfram steel	Nickel	Cobalt
Length.	64.00 cm	64.00 cm	64.00 cm	24 20 cm	27.30 cm
Breadth.	0.903	0.920	0.948	0.510	radius
Thickness.	0.901	0.913	0.953	0.511	=0.680
Elasticity.	2.02×10^{12}	2.01×10^{12}	2.05×10^{12}	1.96×10^{12}	1.79×10^{12}

The present arrangement was not suitable for the absolute measurement of the modulus of elasticity, since the yielding effect of several parts of the arrangement disturbs the result. Hence the modulus of elasticity was determined by the ordinary method of flexure with two mirrors.

The intensity of magnetization of these specimens was determined by the magnetometric method. The results are graphically shown in Fig. 1. Ordinate represents the intensity of magnetization and abscissa the effective field ($H=H'-NJ$).

The magnetic change of length was found to have an intimate relation to the change of elasticity ; it was therefore measured for each specimen. To each end of the bar, a brass rod of the same thickness and 15 cm long was soldered. The bar was there vertically suspended co-axial with the magnetizing coil by means of a screw adjustment. From its lower end, a weight of 1 or $\frac{1}{2}$ kilograms was hung by a copper wire. The rotating cylinder with a mirror was brought

in contact with the wire under suitable pressure, to prevent sliding. The weight was dipped in water so as to avoid its vibratory disturbance. The magnetizing coil was so long that the bar lays nearly in a uniform field. The measurement of the magnetic elongation gave the following results :—

Soft iron.		Steel.		Wolfram steel.		Nickel.		Cobalt.	
H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$	H	$\frac{\delta l}{l}$
9.6	0.45×10^{-6}	19.3	0.08×10^{-6}	16.8	0.13×10^{-6}	16.8	-0.60×10^{-6}	17.0	-0.00×10^{-6}
13.4	0.80	29.4	0.13	24.7	1.18	24.3	−2.66	——	——
20.1	1.65	52.0	0.83	38.6	3.16	34.4	−4.52	38.6	−0.18
30.6	2.63	90.6	0.95	58.3	4.26	54.1	−7.97	70.0	−0.47
67.1	3.48	137.1	0.75	83.9	4.99	76.4	−11.96	113.3	−0.77
113.3	3.06	179.5	0.28	138.4	5.51	124.2	−17.60	176.8	−1.30
204.1	1.40	260.1	−0.58	217.8	5.66	282.5	−24.58	262.6	−2.18
349.9	−1.48	398.2	−1.88	393.7	5.24	405.6	−26.18	399.5	−3.41
510.2	−3.73	512.8	−2.93	500.4	4.99	516.5	−26.84	512.8	−4.12

Here H denotes the effective field and $\frac{\delta l}{l}$ the elongation or contraction per centimeter due to magnetization. These results are also drawn in Fig.2. The curves for soft iron, steel, and Wolfram steel are quite ordinary ; that for nickel, which is not annealed, is less steep than for ordinary annealed nickel. Professor Nagaoka and one of us have already pointed out that the magnetic character of cobalt is much affected by annealing. The curve for cobalt, which was well annealed, shows this abnormity. We shall soon observe that the elasticity of a substance undergoing large magnetic change of length is also much influenced by magnetization.

5. In observing the displacement of the image of the vertical scale in the field of the observing telescope by passing a current through the coils, we were struck with the large effect contrary to

the results of previous experimenters. The largest deflections for soft iron and wolfram steel amounted to adout 9 cm with a scale at a distance of 2.6 meters for a field of 500 C.G.S. units.

The change of depression corresponding to different loadings in soft iron is given in the following table and graphically shown in Fig. 3.

T=110gr		T=610gr.		T=1630gr.		T=2650gr.	
H	δs	H	δs	H	δs	H	δs
7.6	$0{,}26\times10^{-4}$	13.1	1.03×10^{-4}	7.6	-0.17×10^{-4}	10.6	-0.26×10^{-4}
11.7	0.69	18.8	1.89	15.8	1.20	20.1	4.90
15.4	1.35	26.1	4.13	17.9	2.58	26.9	8.77
20.9	2.41	29.0	4.82	24.5	6.19	33.9	11.52
23.6	2.75	36.2	5.50	33.5	8.52	52.9	13.50
33.5	3.61	59.0	6.36	41.4	9.12	69.4	14.27
52.9	4.13	133.4	6.36	55.8	9.63	129.0	14.45
103.7	4.30	231.4	6.36	194.5	9.63	211.7	14.62
233.9	4.13	290.8	6.36	206.8	10.15	289·6	14.79
365.2	4.30	382.5	6.36	437.0	11.04	397.5	15.31

In the above table, the change of depression δs is taken positive when it indicates an increase of elasticity and taken negative, when it indicates a decrease. H is the effective field, and T the suspended weight. It is to be observed that owing to the weight of the bar itself, the depression is caused by magnetization, when there is no suspended weight.

The general course of the curves in Fig. 3 resembles that of magnetization. In weak fields, however, we notice a minute decrease

of elasticity, when the load exceeds about 1.5 kilograms. Iron contracts laterally when magnetized by weak currents, and this contraction may produce such an apparent decrease of elasticity ; but the calculation shows that it is more than can be accounted for by the lateral contraction. When the field increases beyond this region, the change of depression increases rapidly and soon reaches its asymptotic value, after which the increase takes place quite slowly. When the weight is added under a given field, the change of depression is increased. The rate of increase is large with a small weight, and decreases in amount as the weight is increased, approaching an asymptotic value.

From the change of depression, we may calculate the ratio of the change to the modulus itself. The depression due to the suspended weight as well as to its own weight in an unmagnetized bar is given by the approximate formula* $s=\frac{l^3g}{4Eab^3}(T+\frac{5}{8}W)$,
where l, a, b are the length, breadth and thickness of the bar, T and W are the suspended weight and the weight of the bar itself respectively, l and W refer to the part of the bar lying between two fulcrums. The observed change of depression divided by this is the ratio in question, that is, $\frac{\partial E}{E}$. Some of our results of calculation are given in the following table :—

H \ $T\times\frac{5}{8}W$	329 gr.	829 gr.	1349 gr.	1849 gr.	2869gr.
20	1.64×10^{-2}	0.77×10^{-2}	0.50×10^{-2}	0.47×10^{-2}	0.44×10^{-2}
30	2.79	1.47	1.09	1.08	0.88
50	3.15	1.84	1.35	1.28	1.16
100	3.36	1.92	1.48	1.37	1.28
250	3.40	1.93	1.51	1.40	1.32
400	3.40	1.93	1.51	1.40	1.32

*) Clebsch's Elasticität 375 ; Winkelmann's Physik I, 266.

The above results for soft iron approximately agree with those given by the method of elongation both qualitatively and quantitatively. But, the specimens in these two cases are not the same, and moreover $\frac{\delta E}{E}$ is a function of a stress; hence we can not, in a strict sense, conform these two results. Our results, when compared with those of previous experimenters, are markedly large, especially with small loadings.

Wolfram steel. The change of elasticity by magnetization for wolfram steel is quite similar to that of soft iron. The curves of depression is less asymptotic to the axis of the magnetizing force. The initial small decrease of elasticity is more marked than in the case of soft iron and occurs even with the smallest load. The following table and Fig. 4 show the character of the change of depression.

T=110 gr.		T=549 gr.		T=1130 gr.		T=1918 gr.	
H	δs	H	δs	H	δs	H	δs
15.8	-0.05×10^{-4}	14.0	-0.03×10^{-4}	15.1	-0.05×10^{-4}	18.2	-0.34×10^{-4}
20.5	-0.26	19.4	-0.22	18.2	-0.21	20.5	-0.69
23.9	0.34	23.1	-0.03	22.4	-0.24	23.0	-0.21
30.2	0.83	25.4	0.34	25.6	0.36	38.4	8.43
40.7	1.46	36.6	3.44	30.2	3.41	56.5	10.23
62.6	1.93	68.1	4.64	41.1	5.76	75.7	11.09
91.9	2.34	91.9	5.07	68.5	7.09	144.3	11.74
211.9	2.86	269.9	6.02	224.2	8.95	230.2	12.38
384.0	3.44	386.5	6.28	348.1	9.20	360.5	13.07
484.9	3.97	486.0	6.79	472.4	9.56	460.0	13.41

The values of $\frac{\delta E}{E}$ are given in the following table:—

H \ $T+\frac{8}{5}W$	358 gr.	797 gr.	1378 gr.	2206 gr.
70	1.79×10^{-2}	1.88×10^{-2}	1.67×10^{-2}	1.56×10^{-2}
100	2.05	2.02	1.79	1.64
200	2.55	2.27	2.00	1.80
300	2.93	2.42	2.10	1.89
400	3.25	2.60	2.18	1.92
500	3.54	2.68	2.23	1.97

From the last table, we see that the increase of elasticity under a constant field generally becomes less as the load is increased, except in weak fields, in which we notice a maximum as in the case of the elongation method. The ratio of $\frac{\partial E}{E}$ for wolfram steel is several times greater than that by the method of elongation. The principal cause of the discrepancy may probably be due to the fact that the wolfram steel used in the present experiment was magnetically much softer than the specimen used in the former experiment, for the latter was hardened by stretching. It is a well established fact that a hardened iron or steel wire suffers comparatively small magnetic elongation and that the effect of tension on the elongation is also very small. Hence it is to be expected that the result of the method of elongation comes out to be much smaller than that given by the present experiment.

6. *Steel.* Steel shows a comparatively small increase of elasticity; the results of observation are given in the following table and graphically drawn in Fig.5.

T=1005gr.		T=1918gr.		T=2830gr.	
H	∂s	H	∂s	H	∂s
11.8	0.00×10^{-4}	13.4	0.09×10^{-4}	10.3	0.17×10^{-4}
18.8	0.07	27.6	0.43	19.3	0.26
32.2	0.26	43.7	0.95	33.0	1.38
50.5	0.77	85.2	1.89	47.1	2.06
94.7	1.03	170.7	2.58	85.6	2.75
215.6	1.20	199.6	2.49	205.7	3.61
298.5	1.38	292.2	3.05	275.0	3.96
391.6	1.39	386.6	3.27	398.8	4.56
491.1	1.46	487.4	3.44	498.6	4.99

Thus the general character of the change of depression is similar to that of soft iron; but the initial decrease is not observed. The course of the curve is much steeper than in soft iron and wolfram steel, and less asymptotic to the axis of the magnetizing force.

The values of $\frac{\partial E}{E}$ are given in the following table:—

H \ $T+\frac{5}{8}W$	1251gr.	2184gr.	3096gr.
50	0.14×10^{-2}	0.15×10^{-2}	0.17×10^{-2}
100	0.22	0.25	0·25
200	0.27	0.33	0.31
300	0.28	0.37	0.35
400	0.30	0.40	0.39

Thus the increase of elasticity under a constant field reaches a maximum with a load of between 1270 and 2200 grams. On both sides of the load, it gradually decreases as the load is increased or decreased. These results approximately agree with those of wolfram steel obtained by the method of elongation.

Cobalt. The cobalt bar was too thick, and the maximum deflection in the field of the telescope was only 1.5 mm, so that we can not claim for cobalt the same accuracy as in the case of the other specimens. But we notice a distinct increase, as shown in the following table and in Fig.6.

T=1005 gr.			T=2830 gr.		
H	δs	$\frac{\delta E}{E}$	H	δs	$\frac{\delta E}{E}$
21.6	0.00×10^{-4}	0.00×10^{-2}	35.1	0.01×10^{-4}	0.02×10^{-2}
53.0	0.01	0.06	70.3	0.02	0.04
180.5	0.07	0.47	195.6	0.09	0.21
313.4	0.09	0.58	312.1	0.16	0.37
455.1	0.11	0.76	455.1	0.16	0.37

For cobalt, the depression due to the suspended weight is calculated by the formula, neglecting the weight of the bar itself;

$$s = \frac{1}{12\pi}\,\frac{Tl^3}{ER^4},$$

where l and R are the length and the radius of the bar respectively.

Thus the character of the change of elasticity in cobalt is much the same as that in steel.

7. *Nickel.* As regards the change of elasticity by magnetization, nickel shows an abnormal behaviour, as already pointed out in the case of the method of elongation. The following table and Fig.7. are the results of observations :—

T=93 gr.		T=276 gr.		T=549 gr.		T=820 gr.	
H	δs	H	δs	H	δs	H	δs
16.4	-0.15×10^{-4}	10.5	-0.09×10^{-3}	8.4	-0.09×10^{-4}	10.0	-0.28×10^{-4}
24.1	-0.38	16.9	$-0,43$	17.5	-0.98	16.7	-1.17
32.9	-0.45	24.8	-0.67	29.8	$-1,43$	21.9	-1.62
41.8	-0.55	34.5	-1.03	39.2	-1.26	26.4	-1.75
67.8	-0.83	48.1	-0.86	48.9	-1.08	39.6	-1.62
118.1	-0.72	68.2	-0.79	85.1	-0.52	68.2	-0.72
220.0	-0.46	171,7	-0.09	203.9	1.43	117.3	1.17
302.4	-0.17	240.0	0.55	302.4	2.34	217.5	3.18
386.0	0.05	376.0	1.07	399.7	2.79	377.2	4.47
490.8	0.28	496.0	1.46	490.8	3.06	492.1	4.88

The values of $\frac{\delta E}{E}$ are as follows :—

H \ $T+\frac{4}{8}W$	105 gr.	287 gr.	561 gr.	832 gr.
30	-1.80×10^{-2}	-1.60×10^{-2}	-1.30×10^{-2}	-1.08×10^{-2}
70	-4.08	-1.40	-0.70	-0.38
100	-3.84	-0.92	-0.21	$+0.30$
200	-2.50	$+0.46$	$+1.20$	$+1.80$
300	-0.88	$+1.47$	$+2.07$	$+2.52$
400	$+0.42$	$+2.17$	$+2.56$	$+2.83$
500	$+1.34$	$+2.67$	$+2.84$	$+3.03$

Thus, the modulus of elasticity considerably decreases in the weak fields and increases in the strong. The field of no change decreases as the load is increased. The change of depression also increases with the load. In weak fields, the rate of decrease diminishes as the load is increased ; in strong fields, however, the contrary is the case.

Comparing the above results with those given by the method of elongation, we notice that in the present case, the field of no change becomes less, whereas in the former, it becomes greater, as the load is increased, and that the amount of the change is much less in the present case than in the former. Our nickel rod was turned into a square rod from a plate, and the mechanical process, which the specimen underwent, hardened its magnetic quality. The nickel wire used in the preceding experiment was almost chemically pure, and magnetically softer. Hence the discrepancy with regard to the amount of the change may be explained by the difference of the specimens ; but the discrepancy with regard to the field of no change can scarcely be explained by the same fact.

Tangl's results are much smaller than ours, and moreover he did not observe the decrease of elasticity in weak fields, because his initial field was too strong to give such a decrease.

Since nickel steel of suitable dimensions for determining the modulus of elasticity by flexure was not at our disposal, we could not test the result of the method of elongation. But from the above results, we may conclude that the change of elasticity by flexure does not generally coincide with that of elasticity by elongation. As we have observed, the elasticity is no longer independent of the stress applied to the bar ; hence it is possible, and perhaps rather natural, to conclude that in magnetic fields, the elasticity as given by flexure is different from that given by elongation.

In conclusion, we have to express our best thanks to Prof. H. Nagaoka and also to Prof. A. Tanakadate for many valuable suggestions.

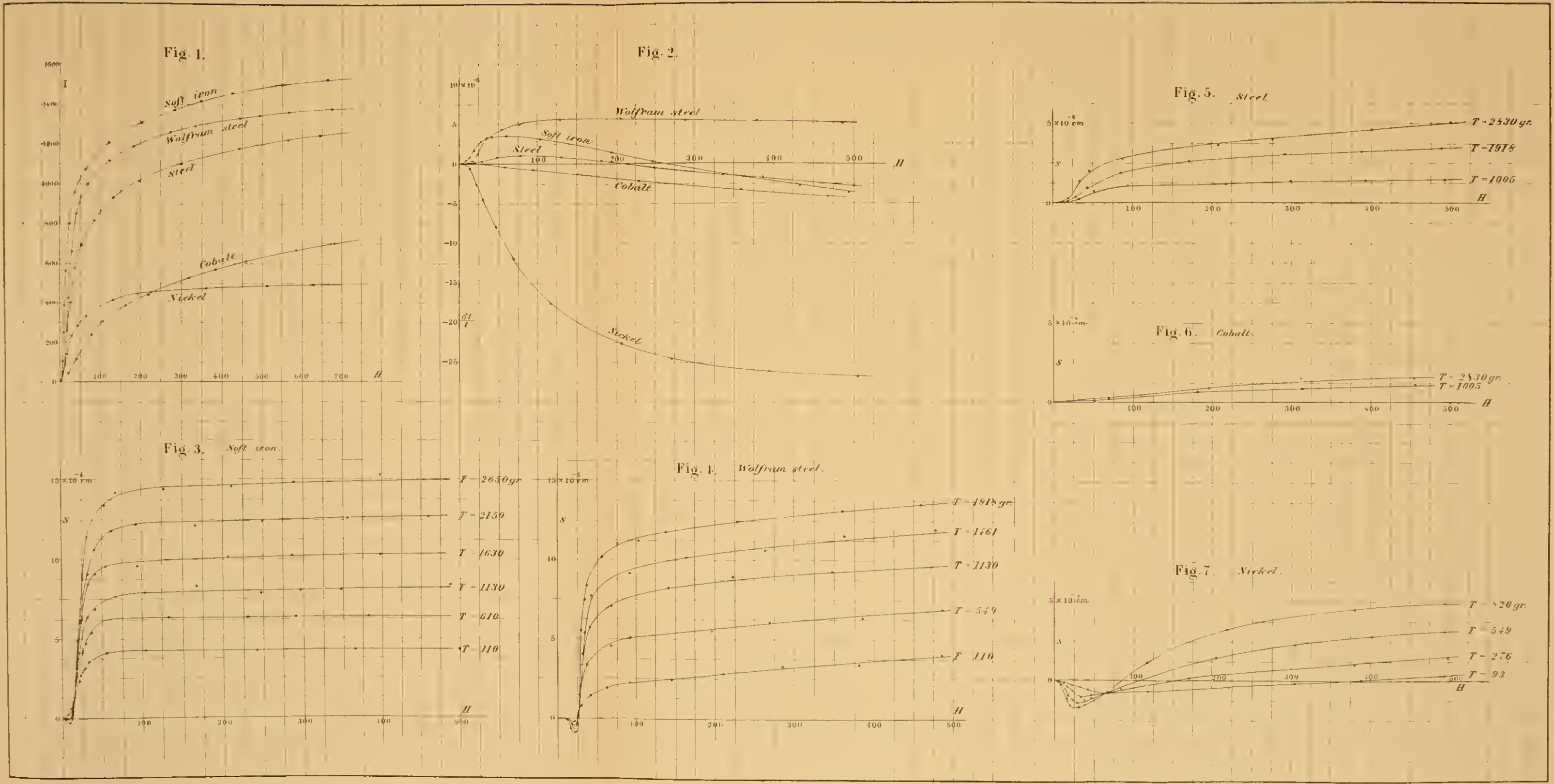


Fig. 1.
Soft iron
Wolfram steel
Steel
Cobalt
Nickel
Fig. 2.
Wolfram steel
Soft iron
Steel
Cobalt
Nickel
Fig. 3. Soft iron.
T = 2650 gr
T = 2150
T = 1630
T = 1130
T = 610
T = 110
Fig. 4. Wolfram steel.
T = 1130
T = 549
T = 110
Fig. 5. Steel.
T = 2530 gr.
T = 1978
T = 1005
Fig. 6. Cobalt.
T = 1005
Fig. 7. Nickel.
T = 549
T = 276
T = 93

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Change of the Modulus of Rigidity in Ferromagnetic Substances by Magnetization.

By

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1. We have already seen that the change of elasticity by magnetization is not so small as has generally been admitted. The present experiment deals with the change of rigidity by magnetization. The investigation is especially important, inasmuch as the change of rigidity by magnetization is reciprocally related to that of magnetization by torsion.

In the course of his experiments on the mutual relations between torsion and magnetism, G. Wiedemann[1] observed that the torsion of an iron wire was diminished by magnetization. This shows an increase of rigidity. C. Barus[2] hung two identical iron wires in the same vertical line, separated by a rigid piece of brass, which carried the index mirror ; to the lower end of the wire, a weight was attached. The wire was twisted and then either the upper or the lower end of the system fastened. If both ends were twisted equally

1) Wiedemann's Electricität III, 796.
2) Barus, Amer. Jour; **34**, 175, 1887 ; Phy. Rev. XIII, 257, 1901.

in opposite directions, the position of the mirror remained unchanged. A magnetizing coil was placed co-axially with the upper wire. If the rigidity of the wire were changed by magnetization, the mirror would rotate in either direction. Barus found that for soft iron and steel, the change of rigidity was 0.24% and 0.08% respectively. In his later experiment, he observed a change of rigidity amounting to 1% for soft iron. With a similar arrangement, H. D. Day[1] investigated the same subject in iron. He found that the change of rigidity increased with the field, and that it became generally less as the initial twist was increased. The maximum value obtained was only 0.8%.

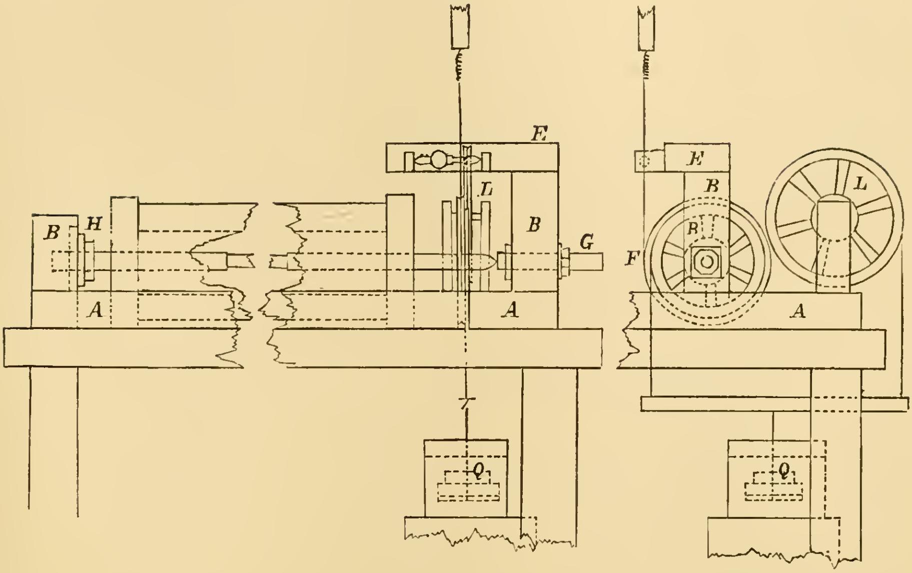
In the experiments of Barus and Day, the tensile stress, which was found to produce a notable effect, would complicate the change to be sought for. Moreover, the lower wire was not perfectly free from magnetization, and the mirror would not give the perfect differential effect.

The experiment of J. S. Stevens[2] for iron and steel rods gave an increase of rigidity by magnetization. The change amounted to 2.3% for soft iron and 0.43% for steel in a field of 138 C.G.S. units. It also increased with the magnetizing force. In his experiment, the length of the magnetizing coil was much less than that of the rod, so that the magnetization was far from being uniform.

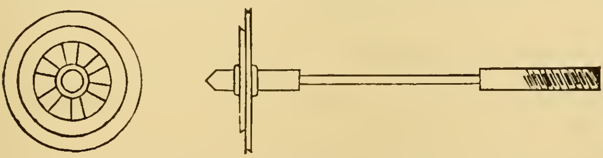
2. Our method of twisting the ferromagnetic rod was the same as that of Professor Nagaoka[3] used for studying the elastic constants of rocks ; but the sensibility of the apparatus was 106.0 times greater for the same scale-distance.

The front and side views of the apparatus are given in the annexed figures.

1) Day, Electrician, **39**, 480, 1897.
2) J. S. Stevens, Phy. Rev. (3) **10**, 161, 1900.
3) Phil. Mag. **50**, 53, 1900.



AA was a stout wooden frame rectangular in shape. BB were the parts projecting from the frame ; to the one, a brass rod, to which a ferromagnetic rod was soldered, was clamped by means of a screw nut H, and to the other, a screw G, which carried an agate cup in one of its extremities, was clamped. F was a double pulley whose axis was a thick brass cylinder ; a point made of nonmagnetic nickel steel was firmly fixed to one of its extremities, while the ferromagnetic rod was soldered to the other, as shown in the following figure. The



inner circumference of the pulley served to twist the rod, and the other to multiply the sensibility of the apparatus. C was a magnetizing coil and E a block of wood, to which a rotating cylinder was affixed as in the case of the former experiment. A fine copper wire, well annealed by passing through it an electric current, was attached to a point on the outer circumference of the pulley and went vertically upward around it. The wire after passing round the

cylinder was stretched by a weak spring in the usual way. The deflection of the mirror attached to the rotating cylinder was observed by means of a scale and telescope. The details of the apparatus will be easily understood from the above figures.

The dimensions of each part of our arrangement were as follows :—

Length of the coil....................	=	30.0	cm,
Its internal diameter..................	=	3.0	,,
$4\pi n$	=	379.7	,,
Outer radius of the pulley }	=	8.93	,,
Inner ,, ,, ,, ,,	=	7.15	,,
Diameter of the rotating }	=	0.160	,,
cylinders	=	0.280	,,
Diameter of the copper wire.........	=	0.008	,,
Scale-distance	=	230.8	,,

If a ferromagnetic rod is twisted through a small angle φ, the thin vertical wire is pulled down through a small distance $R\varphi$, R being the outer radius of the pulley. This causes an elongation of the weak spring attached to the copper wire, and consequently the rotating cylinder, whose radius is r, is turned through an angle $R\varphi/r$ Hence the angle of torsion is magnified in the ratio R : r ; in the actual calculation, we must take into account the thickness of the thin wire. The ratio was in our case 106 : 1 ; with this arrangement, we were able to measure a change of angle amounting to only $1.92'' \times 10^{-3}$ per cm of the ferromagnetic rod.

3. The measurement was conducted in the following order. The specimen to be tested was fixed in the axial line of the magnetizing coil so as to lie nearly in a uniform field. If the steel pivot on one end of the bar carrying the specimen was left free, and a magnetizing current passed through the coil, a deflection of the mirror was observed, though there was no twisting couple. The deflection

is evidently not due to the twisting of the rod, but to its bending by magnetization. The case corresponds to the experiment of Guillemin described in the preceding paper. The nature of the deflection and its amount coincided with the change of elasticity by magnetization, which we have already studied.

The steel pivot was then slightly brought in contact with the agate cup ; if this contact was made in a suitable degree, the deflection due to magnetization, when acted on by no twisting couple, could be made negligibly small. In case the deflection could not be sufficiently reduced, it was always corrected for. The contact being so adjusted, a couple was applied by suspending a weight. The tension of the copper wire was next adjusted and the working of the apparatus tested by adding successively weights of 1, 10, 50 grams to the pan. If the deflections of the mirror were proportional, the adjustment was considered to be correct.

To begin with, the ferromagnetic rod was demagnetized by reversals, and then a current passed, taking the deflection as soon as possible. These processes were repeated with successively increasing currents. In order to prevent minute oscillations of the mirror, the thin copper wire and the mirror should be protected from the air currents.

The resistance of the magnetizing coil was only 0.6 Ω, so that the heating of the core due to current was negligibly small up to the strongest current used in the present experiment, and the creeping of the image of the scale was not at all observed. But we were careful to read the deflection as quickly as possible.

Since the couples corresponding to 1, 10, 50 grams produced torsions proportional to their respective weights, the friction at the pivot did not seem to disturb our results. That the observed deflection was really due to a rotation, but not to the depression or eleva-

tion of the pulley, was verified in the following way. The fine copper wire was fixed to the axial line of the pulley and the depression or elevation of the axis itself due to magnetization of the ferromagnetic rod was observed by means of a rotating cylinder carrying a mirror. A minute deflection amounting to only a fraction of a millimeter was noticed, whereas the deflection was several centimeters when the copper wire was fixed to a point on the circumference of the pulley. Hence the actual depression or elevation of the axis, if any, was negligibly small.

The samples to be tested were the same as those used in the former experiment, except in the case of the nickel rod.

In the present experiment, the length of each rod was reduced to 22 cm, and the diameter of the cobalt bar also to 1.082 cm. The nickel rod, used in the former experiment was turned into a square rod from a plate, and the mechanical process, which the specimen underwent, hardened it in magnetic quality. Moreover the nickel was not sufficiently thick for the torsion experiment, so that another nickel bar, the diameter of which was 1.117 cm, was substituted for it. The new specimen was turned into a cylindrical form from a thick bar, and was magnetically much softer.

Our apparatus was not suited for the absolute measurement of the modulus of rigidity and therefore its determination was, in the usual manner, carried on with Professor Nagaoka's apparatus above referred to. The results were :

Metal	Soft iron	Steel	Wolfram steel	Nickel	Cobalt
Rigidity	7.92×10^{11}	7.89×10^{11}	8.57×10^{11}	7.41×10^{11}	6.04×10^{11}

4. *Soft iron.* The rigidity of soft iron is always increased by magnetization, as will be seen from the following table and Fig. 1.

SOFT IRON.

$N=7.89\times10^6$ $\theta=22''.11$		$N=14.36$ $\theta=40''.21$		$N=20.87\times10^6$ $\theta=58''.45$		$N=27.48\times10^6$ $\theta=76''.96$		$N=33.96\times10^6$ $\theta=95''.13$	
H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$
7.5	4	7.3	14	7.3	15	7.3	23	7.3	25
11.0	11	11.1	25	11.1	38	11.1	50	11.1	50
17.2	34	17.0	58	17.2	84	17.0	105	17.0	119
29.6	61	28.6	123	29.4	186	28.6	218	28.6	260
57.4	117	55.5	224	56.8	329	54.3	406	55.8	481
99.2	159	92.4	299	98.4	446	92.4	550	96.4	661
189.9	193	187.8	379	171.0	530	169.9	676	169.9	783
295.4	214	284.7	423	295.4	603	295.4	776	295.4	908
542.9	230	442.9	456	542.9	649	438.3	843	443.0	994
587.5	247	587.5	477	585.3	680	580.9	887	583.1	1054
802.9	257	802.9	500	802.9	711	800.5	923	805.1	1095

Here N denotes the moment of force expressed in C.G.S. units, θ'' the angle of torsion per cm corresponding to the moment, as calculated from the rigidity, and $\delta\theta''$ the observed change of torsion due to magnetization, given in seconds of arc. $\delta\theta$ is taken positive when the change of twist indicates an increase of rigidity and taken negative when it indicates a decrease. H is the effective force ($=H_0$—IN).

Thus, the untwisting of the rod always increases with magnetization, its amount increasing in the same way that the intensity of magnetization is related to magnetizing force. As the moment of force increases, the amount of untwisting increases proportionally, so that the change of rigidity is fairly independent of the twisting couple for all magnetizing fields. The form of the curves is similar to that of the curves of depression in the former experiment, except in very weak fields. In the present case, the initial minute depression of the curves was not observed.

From the angle of torsion and its change, we calculated the ratio of the change (δK) to the rigidity (K) itself. The ratio is fairly independent of the twisting couple for all fields ; in the following table, mean values for the different couples are given.

H	20	60	100	200	400	600	800
$\frac{\delta K}{K}$	0.0019	0.0058	0.0076	0.0096	0.0110	0.0118	0.0122

These values are also plotted against the magnetizing force in Fig. 2 ; the course of the curve resembles that of magnetization, having one inflexion point and approaching to an asymptotic value as the field is increased.

The untwisting by magnetization forms a reciprocal relation to the well known fact that the magnetization of iron decreases by twisting.

The above results for soft iron agree in quality with those of previous experimenters, and the amount of the change nearly coincides with some of Barus' results. In the experiment of Day, the change of rigidity was a little smaller than in the present case, and was greatly influenced by the amount of the twisting couple in contradiction to our results. Stevens' experiment gave a much greater increase of rigidity.

Wolfram steel. As we have already found the change of elasticity in wolfram steel due to magnetization is nearly the same as that of soft iron both in quality and in quantity. This remark also applies to the present case, so that what we have said about the change of rigidity in soft iron equally applies to the case of wolfram steel.

This will be seen from the following tables and Figs. 3 and 2 :

$N=7.89\times10^6$ $\theta=16.''58$		$N=14.36\times10^6$ $\theta=30.''17$		$N=20.87\times10^6$ $\theta=43.''85$		$N=27.48\times10^6$ $\theta=57.''74$		$N=33.96\times10^6$ $\theta=71.''37$	
H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$
15.3	6	15.3	21	15.4	31	15.3	27	15.4	33
19.2	27	19.1	62	19.1	85	19.1	88	19.2	121
23.6	60	22.7	108	23.6	163	23.5	188	23.6	223
35.1	90	33.1	167	33.1	240	34.9	267	35.2	348
55.0	115	54.6	206	54.6	289	54.5	360	54.8	441
92.1	138	91.1	246	91.1	354	90.3	446	92.1	546
169.5	156	169.5	294	169.5	414	169.5	529	169.5	658
290.1	175	291.0	321	289.5	456	289.1	596	289.1	731
437.6	183	436.9	342	436.9	490	434.1	631	429.8	783
579.1	194	579.1	356	579.1	510	576.9	664	574.6	818
785.6	200	787.8	375	785.6	533	783.6	702	783.4	864

H	20	60	100	200	400	600	800
$\dfrac{\delta K}{K}$	0.0015	0.0073	0.0085	0.0098	0.0110	0.0116	0.0122

5. *Steel.* We have seen that in steel, the change of elasticity by magnetization is much smaller than in soft iron. So, in the case of rigidity, we also observe a comparatively small increase. The following table contains the results of our observations :—

$N=7.89\times10^6$ $\theta=20.''82$		$N=14.36\times10^6$ $\theta=37.''88$		$N=20.87\times10^6$ $\theta=55.''05$		$N=27.48\times10^6$ $\theta=72.''50$		$N=33.96\times10^6$ $\theta=89.''60$	
H	$\delta\theta'''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$
14.6	1	14.4	5	14.4	10	14.4	10	14.6	17
28.6	10	28.6	27	28.6	38	29.0	60	30.4	77
70.9	25	70.9	58	71.5	83	70.7	117	65.2	148
189.7	40	190.6	87	189.7	133	187.9	181	187.9	223
307.6	46	307·6	100	304.5	160	304.5	214	305.5	256
448.5	52	448.5	112	450.7	179	444.1	229	448.4	283
590.5	60	588.4	121	590.5	188	588.4	246	588.4	302
794.2	63	794.2	129	792.0	206	792.0	262	794.3	321

These numbers are graphically shown in Fig. 4. We see that the form of the curves is much less steep than in those for soft iron or wolfram steel.

Here again, the change of rigidity is independent of the applied couple; the values of $\frac{\delta K}{K}$ for different fields are given in the following table and in Fig. 2:—

H	60	200	400	600	800
$\frac{\delta K}{K}$	0.0013	0.0022	0.0029	0.0032	0.0035

The results of the previous experimenters fairly agree with those of the present case. The reciprocal relation between torsion and magnetism also holds for steel.

Cobalt. As in the case of steel, the effect of magnetization upon the rigidity of a cobalt bar is very small. The rigidity always increases by magnetization, as shown in the following tables and Figs. 5 and 2:—

$N=14.36\times10^6$ $\theta=36.''46$		$N=27.48\times10^6$ $\theta=69.''78$		$N=40.48\times10^6$ $\theta=102.''79$	
H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$
46.4	3	46.4	7	46.4	11
96.3	17	106.3	38	106.0	60
217.9	46	209.2	90	210.2	142
328.9	69	330.9	133	330.9	190
470.7	81	472.8	163	474.9	233
609.2	96	611.5	189	611.5	269
808.2	106	820.4	214	820.4	317

H	100	200	400	600	800
$\frac{\delta K}{K}$	0.0005	0.0012	0.0021	0.0028	0.0031

Thus the course of the curves is less steep in cobalt than in steel ; the inflexion point is not so marked in the former metal as in the latter. The change of rigidity is also independent of the applied couple.

So far as we are aware, the effect of torsion on the magnetization of cobalt has not yet been studied, on account of the difficulty of getting the specimen in the form of a wire. But if the reciprocal relation holds in the case of cobalt, the above results show that the effect of torsion on the magnetization of cobalt is the same as in iron. We have seen from the experiment of Professor Nagaoka and one of us that the character of cast cobalt as regards magnetostriction is remarkably different from that of annealed cobalt. The cobalt in the present experiment was well annealed, so that the above inference is to be restricted to an annealed cobalt.

6. *Nickel.* The change of rigidity of the nickel bar was so large that it was necessary to reduce the sensibility of the apparatus by using a rotating cylinder of greater diameter. As in the case of elasticity, we again observe in the metal the singular phenomenon that the change of torsion by magnetization alters its sign as the magnetizing force is increased. The following table contains the results of the observation, which are also drawn in Fig. 6.

$N=4.65\times10^6$ $\theta=8.''47$		$N=7.89\times10^6$ $\theta=14.''37$		$N=11.09\times10^6$ $\theta=20.''19$		$N=14.36\times10^6$ $\theta=26.''14$		$N=17.56\times10^6$ $=31.''96$	
H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$	H	$\delta\theta''\times10^3$
11.5	— 3	11.4	— 15	11.7	— 30	11.4	— 59	11.4	— 69
14.8	— 33	14.6	— 69	14.6	—102	14.6	—157	14.6	—177
24.5	—108	24.5	—190	24.5	—272	24.5	—351	24.5	—433
39.1	—144	39.0	—242	39.0	—347	38.7	—433	38.0	—534
62.8	—102	62.7	—167	61.1	—256	61.8	—328	61.5	—406
96.1	— 7	96.1	— 10	95.3	— 33	94.2	— 39	94.2	— 49
140.5	102	139.5	177	137.8	252	138.9	315	138.4	374
229.3	262	223.9	452	226.1	645	226.6	822	244.8	1088
354.1	419	352.3	721	349.1	996	350.1	1274	349.1	1543
504.5	528	475.3	888	500.2	1248	504.7	1612	502.3	1946
649.6	596	649.1	1019	645.2	1415	649.7	1808	645.2	2214
867.1	655	867.1	1120	862.6	1566	864.8	1998	864.8	2447

Thus in weak fields, the deflection shows a farther twisting of the nickel, that is, a decrease of rigidity. This decrease reaches a maximum as the field becomes stronger ; it then begins to decrease, and in a field of about 100 C.G.S. units, the rigidity returns to its original value. When the field is farther increased, the rigidity rapidly increases, and after passing an inflexion point, its rate of increase becomes gradually less. Thus the character of the change is quite analogous to that of the change of elasticity.

In a given field, the amount of torsion or detorsion due to magnetization is proportional to the applied couple, so that the change of rigidity is independent of the couple for all magnetizing fields. It is also a proof of the fact that the curves corresponding to different couples pass through a point on the axis of the field. The ratio of the change to the modulus itself for different fields are given in the following table and in Fig. 2 :—

H	20	40	80	100	200	400	800
$\frac{\delta K}{k}$	-0.0096	-0.0168	-0.0067	0.0012	0.0263	0.0532	0.0748

Thus in nickel, the ratio is rather large compared with other ferromagnetics. In the former experiment, the change of elasticity of the same metal, even in a hardened state, was rather large. If we should study the change of elasticity with the present sample, proportionally large changes would be observed. That this inference is probably correct, may be seen from the results of the method of elongation ; in this case, a well annealed nickel wire was examined, and a large change of elasticity amounting to about 6 % was obtained.

According to Professor Nagaoka[1] and Zehnder[2], the magnetization of nickel increases by twisting in weak fields ; in strong fields, however, it diminishes by twisting. These results are reciprocally related to ours.

The change of torsion thus far described for iron, steel, cobalt and nickel is independent of the direction of the magnetizing force.

From the above result, we may conclude that in ferromagnetic substances, which undergo a large change of elasticity, there is also a proportionally large change of rigidity, and that the natures of their changes are parallel to each other.

7. In comparing the change of rigidity by magnetization with that of elasticity, we observe the one marked difference that the change of rigidity is independent of the applied stress, while that of the elasticity is largely influenced by it, especially in small stress. Hence it may be suspected that the observed change of elasticity may

1) Nagaoka, Jour. Coll. Sci., Tokyo **2**, 304, 1888 ; **3**, 189, 1889.
2) Zehnder, Wied. Ann. **41**, 210, 1890.

contain terms, which can not properly be considered as the change of elasticity. If this be the case, the change of elasticity by magnetization is only apparent.

In conclusion, it may be noted that the reciprocal relations between torsion and magnetism, as found by actual experiments, will be found to be of paramount importance in the theory of magnetostriction. We may conveniently place the results of our experiments in the following statements parallel with those of previous investigators :—

MAGNETIZATION TO TWIST.	TWIST TO MAGNETIZATION.
(*a*) The magnetization of iron decreases by twisting for all magnetizing fields.	(*a'*) The torsion of iron decreases in all magnetizing fields.
(*b*) The magnetization of nickel increases by twisting in weak fields.	(*b'*) The torsion of nickel increases in weak fields.
(*c*) The magnetization of nickel decreases by twisting in strong fields.	(*c'*) The torsion of nickel decreases in strong fields.

A similar reciprocal relation would probably exist in the case of cobalt. The actual verification of the relation will be undertaken in the near future.

We have to express our cordial thanks to Professors H. Nagaoka and A. Tanakadate for valuable suggestions in the carrying out of the present experiment.

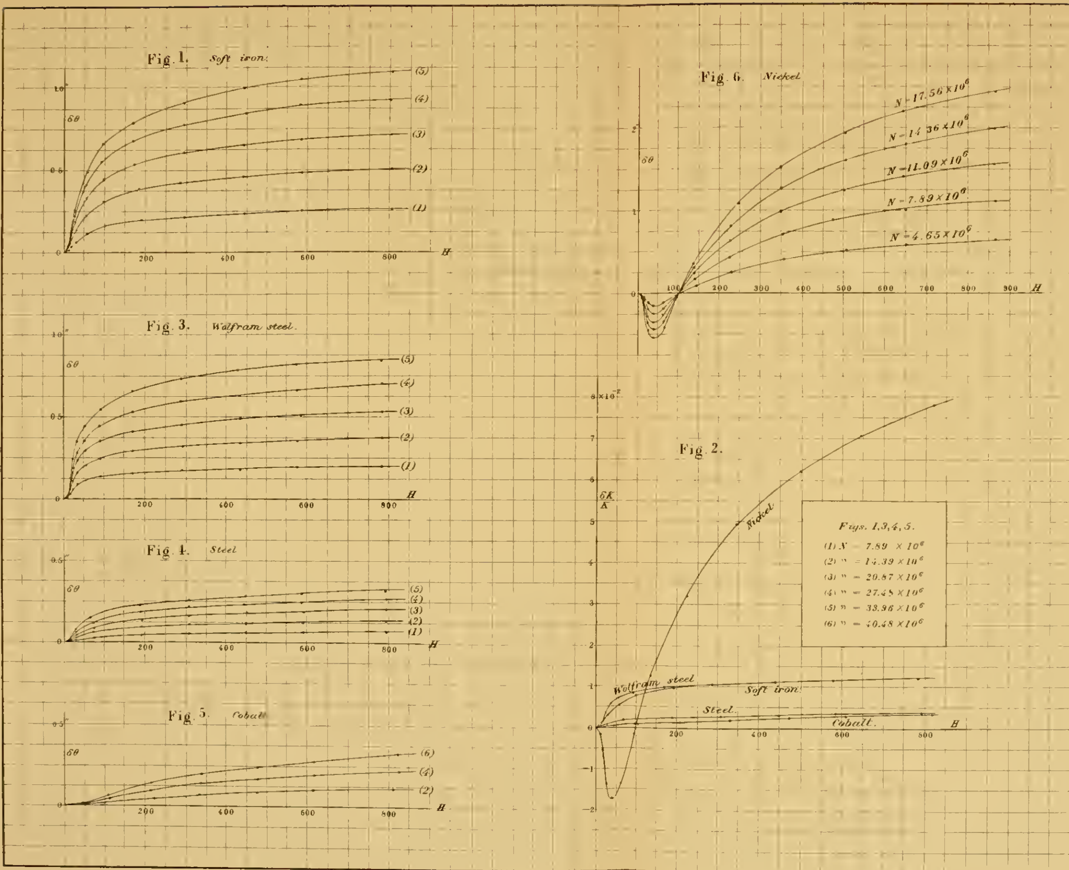


Fig. 1. Soft iron.
Fig. 3. Wolfram steel.
Fig. 4. Steel.
Fig. 5. Cobalt.
Fig. 6. Nickel.
N = 17.56 × 10^6
N = 14.36 × 10^6
N = 11.09 × 10^6
N = 7.89 × 10^6
N = 4.65 × 10^6
Fig. 2.
Nickel
Wolfram steel
Soft iron
Steel
Cobalt
Figs. 1,3,4,5.
(1) N = 7.89 × 10^6
(2) " = 14.39 × 10^6
(3) " = 20.87 × 10^6
(4) " = 27.45 × 10^6
(5) " = 33.96 × 10^6
(6) " = 40.48 × 10^6

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The Wiedemann Effect in Ferromagnetic Substances.

By

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With Plates I–III.

The Wiedemann effect in iron and nickel is so well known that it is superfluous to enter into the details of the phenomenon. The experiments by G. Wiedemann,[1] C. G. Knott,[2] Professor Nagaoka and one of our members[3] show that so long as the longitudinal field is not strong, the direction of twist in iron coincides with that of a circular field, if this direction is right-handedly related to that of the longitudinal field ; they also show that in nickel the direction of twist is opposite to that of iron. In strong field, however, the direction of twist in iron is reversed, so that iron and nickel are twisted in the same direction. The direction of twist is reversed, when one of the circular and longitudinal fields changes its direction. Wiedemann effect in nickel steels of different percentages was recently studied by Professor Nagaoka and one of our members, and it was found that the direction of twist was the same as that of iron. The effect of tension on the Wiedemann effect in iron and nickel was

1) G. Wiedemann, Pogg. Ann. **103**, 571, 1858 ; **106**, 161, 1859 ; Electricität III, 797.
2) Knott, Trans. Roy. Soc. Edinb.. **32** (1), 193, 1882/83 ; **35** (2), 377, 1889 ; **36** (2), 485, 1891.
3) Nagaoka and Honda, Jour. of Coll. of Sci., XIII, 263, 1900.

examined by C. G. Knott who found that the tension diminished the angle of twist in these metals.

The present paper consists of two parts: firstly we deal with the influence of tension on the Wiedemann effect in nickel steels, and secondly with the same effect in ferromagnetic bars and the effect of torque on it. We lately published a paper relating to the effect of tension on the magnetic change of length ; in this we found that the magnetic elongation of nickel steels is largely affected by tension, and that when the tension exceeds a certain value, the contraction is accompanied by magnetization. From Maxwell and Crystal's explanation as well as from that of Kirchhoff for the Wiedemann effect, it seems probable that the direction of twist in nickel steels is reversed, when the suspended weight exceeds the said limit. We therefore studied this point particularly and found that the above inference is not correct.

So far as we are aware, Wiedemann effect in cobalt has not yet been studied, perhaps because it is difficult to obtain a specimen in the form of a wire on account of its brittleness. It was therefore desirable to have an experiment for the metal. Our apparatus used in studying the change of rigidity by magnetization was conveniently used for examining the Wiedemann effect of ferromagnetic bars. We had two cobalt bars, one in the cast state and the other in the annealed. The observations showed that the torsion in cobalt was opposite to that of iron, as was to be expected from the change in length by magnetization.

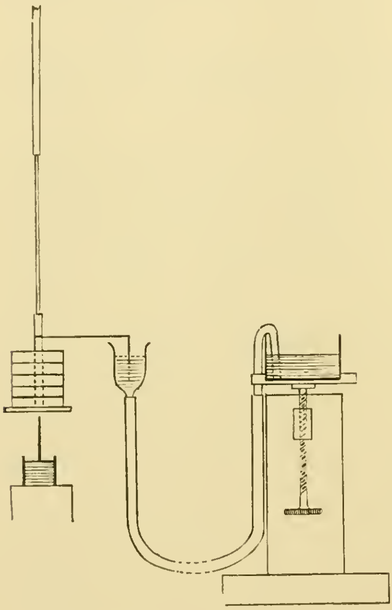
We tested 8 different samples shown in the following table :—

Metal.	Length.	Diameter.
45% nickel steel	20.80 cm.	0.0956 cm.
,, ,, ,, ...	20.90	0.0516
35% nickel steel	20.92	0.0939
,, ,, ,, ...	20.96	0.0509
Soft iron bar	21.03	1.004
Nickel bar	21.00	1.117
Cast cobalt bar	21.00	1.038
Ann. cobalt bar	21.00	1.082

Our arrangement for studying the Wiedemann effect in nickel steel wires was the same as that used by Professor Nagaoka and one of our members in the experiment described in the paper above referred to.

To the extremities of a nickel steel wire 21cm. long were brazed stout brass wires, and a light mirror was attached to the lower brass wire. The upper wire was clamped to a small tripod, which rested on the top of a magnetizing coil provided with hole, slot, and plane arrangement. One end of the accumulator was connected with the tripod, while the other was led to the mercury pool placed under the suspended wire. The wire hung vertically in the axial line of the coil, which was 30cm. long and gave a field of 37.97 *C.G.S.* units at the center by passing a current of one ampere. The vertical component of the terrestrial magnetic field was compensated by placing another coil in the interior of the magnetizing coil. The twist was measured by scale and telescope, by which a torsion of 0.2″ per cm. was easily read.

The preliminary experiment showed that the resistance to the twist offered by the mercury in the pool was not negligibly small, when the thick brass wire was dipped into the mercury. The resistance was especially noticeable, when the brass wire carried a narrow rectangular piece for the purpose of damping. Hence in order to efface the resistance, a non-magnetic nickel steel wire 0.5mm. thick and 5cm. long was soldered to the lower end of the brass wire and dipped into the mercury pool. By this, the damping of the torsional oscillation was rendered very small, especially in the case when a weight was attached. To stop the oscillation, a brass wire was fixed horizontally to the vertical wire and bent downward as shown in the annexed figure. Just below it, a small mercury cup was placed; this cup was connected with a large one by a caoutchouc tube. This large cup was placed near the observers and could be raised or lowered by means of a screw adjustment. This motion caused the mercury in the small cup to be raised or lowered, so that the side wire dipped into the mercury, or hung free. When we wished to stop the oscillation of the wire, the side wire was dipped into the mercury in the small cup; while the reading was always taken with the wire hanging free of the mercury.



The experiment was conducted in the following manner:—

1. The circularly magnetizing current was kept constant, and the amount of twist measured by varying the longitudinally magnetizing current.

2. The wire was then stretched by different loads and the above processes were repeated.
3. The longitudinally magnetizing current was kept constant, and the amount of twist measured by varying the circularly magnetizing current.

Before each experiment care was taken to demagnetize the wire completely either longitudinally or circularly by passing an alternate current of gradually diminishing intensity. This was found absolutely necessary to secure correct results.

Twist by varying the longitudinal field. If the direction of the longitudinal field is right-handedly related to that of the circular field, nickel steel is twisted in the direction of the latter. As shown in Figs. 1 and 2, under a given circular field, the amount of twist at first increases till it reaches a maximum, after which it gradually diminishes. But the reversal of the twist is never observed, though the field exceeds 1200 *C.G.S.* units. The position of the maximum twist is slightly displaced in high fields as the longitudinal current increases. The amount of twist is greater in 45% nickel steel than in 35% nickel steel. Some observed readings are given in the following tables :—

45% nickel steel.

$C=0.95$ amp.		$C=1.93$ amp.		$C=3.00$ amp.	
H	θ	H	θ	H	θ
0.2	2.2″	0.2	3.6″	0.2	3.7″
3.6	21.7	2.0	20.6	4.5	41.6
9.3	27.0	6.7	43.2	6.9	54.8
17.3	25.3	11.5	47.7	19.7	66.4
32.0	19.9	31.7	39.8	33.0	57.8
51.2	15.3	51.3	31.1	51.7	45.5
89.2	9.9	89.6	20.3	91.3	29.9
158	5.5	158	12.2	163	17.7
277	2.5	283	7.3	296	9.9
462	1.4	462	4.1	496	5.9
655	0.3	655	2.8	727	3.7

35% nickel steel.

$C=0.76$ amp.		$C=1.59$ amp.		$C=3.09$ amp.	
H	θ	H	θ	H	θ
0.3	1.8″	0.3	2.2″	0.3	2.9″
1.9	5.8	0.8	4.9	1.8	14.5
5.0	11.8	3.0	15.3	5.0	31.4
10.0	14.9	9.6	27.6	10.7	40.8
25.5	12.3	20.9	25.1	17.6	41.2
38.6	9.8	30.3	21.2	28.7	32.0
51.4	8.0	51.3	14.7	51.3	22.0
89.6	5.1	102.8	8.2	102.8	12.7
183	2.6	204	4.3	205	7.3
352	1.6	448	2.1	448	3.9
619	0.9	668	1.7	668	2.9

Here C denotes the current per square millimeter, H the external field and θ the angle of twist per centimeter. In the experiment above cited, Professor Nagaoka and one of us observed in some cases the reversal of the direction of twist in 45% nickel steel ; but in the present experiment, we did not notice this reversal of twist.

The effect of tension. The effect of tension on twist in nickel steels is not so marked as that of tension on the magnetic change of length in the same metal. As seen from Figs. 3 and 4, the tension always diminishes the amount of twist; the diminution is large in weak fields and becomes gradually less as the field is increased, till it becomes insensibly small. The diminution is approximately proportional to the applied tension.

To test the effect of heavy loading, thin wires about $\frac{1}{2}$mm. thick were examined. Even by a tension in which contraction occurs by magnetization, the direction of torsion in nickel steels is not reversed, though the amount of the maximum twist is reduced to about ^{1} or $\frac{1}{5}$ its value corresponding to no tension, as seen from Figs. 5 and 6.

Whichever theory we adopt, whether Maxwell's or Kirchhoff's, the direction of twist is principally determined by the sign of the quantity $3\lambda-\sigma$, where λ and σ are respectively the length- and the volume-change of the ferromagnetics. When there is no tension acting on the wire, the sign of $3\lambda-\sigma$ must be positive, because the direction of twist in the alloy is the same as that of iron. By applying a heavy load, the contraction is accompanied by magnetization so that λ is negative. Hence in order that $3\lambda-\sigma$ should be positive, σ must necessarily be negative under heavy loading ; that is, the change of volume by magnetization must change its sign from positive to negative, as the load is increased.

Twist by varying the circular field. In Figs. 7 and 8, we notice that under a constant longitudinal field, the angle of twist at first increases at a constant rate, but later at a gradually diminishing rate. As the longitudinal field is increased, the curves approximate to right lines, a result which is to be expected from Kirchhoff's theory of magnetostriction. For according to the theory, if the circular field is small compared with the longitudinal field, the amount of twist for a given longitudinal field is proportional to the longitudinal current. The amount of twist is greater in 45% nickel steel than in 35% nickel steel.

From Figs 7 and 8, we can obtain the twist under a given longitudinal current by gradually increasing the longitudinal field ; the result so obtained, if it is compared with Figs. 1 and 2, shows that the twist produced by the interaction of the circular and longitudinal fields is independent of the order of applying them.

Some observed angles of twist are exhibited in the following tables :—

45% nickel steel.

$H=4.8$		$H=12.8$		$H=66.5$		$H=323.0$	
C	θ	C	θ	C	θ	C	θ
0.25	4.9″	0.14	3.7″	0 27	3.6″	0.21	0.5″
0.45	10.0	0.40	9.4	0.62	8.3	0.59	1.8
0.99	22.1	0.99	25.0	0 82	10.8	1.13	3.5
1.69	33.3	1.75	41.6	1.41	19.0	1.55	4.4
3.00	43.0	2.53	55.4	2.06	26.6	2.40	7.5
—	—	3.64	70.2	3.39	41.4	3.47	11.0

35% nickel steel.

$H=2.1$		$H=13.8$		$H=32.7$		$H=89.6$	
C	θ	C	θ	C	θ	C	θ
0.29	2.0″	0.15	2.4″	0.25	3.4″	0.24	1.5″
0.56	3.7	0.56	9.6	0.56	7.5	0.57	3.5
1.05	7.6	1.05	18.0	1.05	13.5	1.05	6.2
2.23	13.7	2.24	35.0	2.06	24.1	2.04	12.2
3.08	15.7	3.07	40.8	3.10	31.8	3.07	15.7

The apparatus for studying the Wiedemann effect in ferromagnetic bars was that used in the experiment on the change of rigidity by magnetization ; the longitudinal current was led to the bar by means of mercury contact without causing sensible resistance. The ferromagnetic bar was soldered on both ends to brass bars of a thicker diameter, as in the former experiment just referred to. It was fixed, by means of the screw nut at one end of the bar, in the axial line of the magnetizing coil, which was placed magnetic east and west. The pivot at the other end of the bar carrying a double wheel was lightly placed in contact with the agate cup fixed to the wooden frame. The twist was measured by means of a rotating cylinder with a reflecting mirror, a vertical scale and a telescope. Since the Wiedemann effect is an odd function of longitudinal or circular fields, it is easily distinguishable from other effects such as the change of elasticity or that of rigidity, which is an even function of the field. Preliminary experiments showed that the circular field has no effect upon the modulus of elasticity or of rigidity, perhaps because the field is not strong enough to cause such changes. They also showed that the friction at the pivot is not sensible ; for the amount of twist when the pivot is left free or when it is supported, gave almost coincident values. The

direction of currents was also so chosen that the rotation of the mirror causes contraction of the weak spring stretching the thin copper wire. With the present apparatus, the twist amounting only to $1.83'' \times 10^{-3}$ per cm. of our specimen was easily read.

The measurement was conducted in the same order as in the case of nickel steels. Here we noticed that a slight residual magnetism considerably affected our results; hence before each deflection was taken, demagnetization was carefully effected.

Twist by varying the longitudinal field. Fig. 9 represents the curves of twist per cm. in an iron bar plotted against the external longitudinal field. Here C is the longitudinal current per square centimeter. The general course of the curves is similar to that observed in the wire of the same metal. Under a constant circular field, the angle of twist increases at first slowly and then rapidly, till it reaches a maximum in a field of about 100 *C.G.S.* units; it then diminishes and ultimately changes its direction. The field in which the twist reaches a maximum, and also the field of reversal are markedly larger in the bar than in the wire. Moreover, the diminution of twist in the bar, after reaching a maximum, is comparatively slow.

The results for nickel are drawn in Fig. 10; the general features of the curves are similar to those in the wire of the same metal. The direction of twist is opposite to that in iron; but the course of the curves is similar to that in iron, the only difference being that even in strong fields, the direction of twist is not reversed. The field in which the twist reaches a maximum is also considerably larger in the bar than in the wire, and the diminution of twist, after reaching a maximum, is comparatively slow.

The direction of twist in cobalt is the same as in nickel. In cast cobalt, the amount of twist is rather large, as shown in Fig. 11. The twist increases at first slowly and then rapidly, till it reaches a

maximum ; it then gradually decreases and ultimately changes its direction as the field is increased. Thus, the course of the curves is just the reverse of that in iron.

The behaviour of annealed cobalt as regards the Wiedemann effect is remarkably different from that of cast cobalt, as shown in Fig. 12. In the first place, the amount of twist is much smaller in the annealed than in the cast cobalt. Secondly, the field in which the twist reaches its maximum is rather large in annealed cobalt. Thirdly, the decrease of the twist after its maximum value is very slow and its direction does not change, though the field is pushed to 1200 *C.G.S.* units. These results for annealed as well as for cast cobalt are just what is to be expected from the magnetostriction of these specimens. It is also to be observed that these cobalt bars were made of different samples.

The following tables contain some observed angles of twist for iron, nickel, and cobalt bars :—

Iron bar.

$C=0.64$ amp.		$C=3.12$ amp.		$C=5.26$ amp.		$C=8.86$ amp.	
H	θ	H	θ	H	θ	H	θ
12.8	0.004″	12.3	0.029″	11.5	0.016″	12.3	0.069″
25.3	0.013	25.0	0.051	22.4	0.064	22.9	0.154
36.9	0.026	36.5	0.135	36.5	0.213	36.5	0.415
54.8	0.055	54.6	0.269	54.6	0.463	54.6	0.755
83.7	0.084	83.9	0.445	83.7	0.663	83.6	0.942
127.2	0.080	127.2	0.380	127.2	0.597	127.2	0.781
188	0.068	188	0.292	188	0 384	188	0.565
277	0.042	275	0.171	276	0.245	275	0.318
416	0.016	416	0.092	416	0.110	416	0.159
513	0.005	513	0.065	512	0.096	512	0.101
734	−0.005	729	0.016	726	0.053	726	0.040

Nickel bar.

C=1.30 amp.		C=2.60 amp.		C=4.37 amp.		C=6.55 amp.	
H	θ	H	θ	H	θ	H	θ
10.0	−0.141″	7.1	−0.183″	7.7	−0.297″	6.9	−0.336
14.4	−0.201	15.5	−0.424	15.7	−0.629	14.4	−0.767
26.4	−0.294	25.1	−0.632	25.0	−0.893	23.8	−1.158
40.6	−0.327	35.9	−0.705	35.9	−1.020	35.9	−1.372
53.3	−0.283	54.1	−0.684	53.8	−1.005	54.0	−1.358
81.1	−0.204	82.6	−0.523	81.5	−0.810	81.9	−1.125
123.8	−0.117	124.6	−0.367	124.8	−0.585	125.0	−0.840
186	−0.058	187	−0.236	187	−0.386	187	−0 595
270	−0.029	271	−0.141	272	−0.232	272	−0.391
408	−0.025	413	−0.086	408	−0.155	394	−0.292
512	−0.020	520	−0 065	512	−0.143	513	−0.223
670	−0.011	705	−0.040	708	−0.073	705	−0.143
797	−0.004	801	−0.024	802	−0.068	801	−0.104

Cast cobalt bar.

C=2.34 amp.		C=4.75 amp.		C=9.19 amp.		C=17.22 amp.	
H	θ	H	θ	H	θ	H	θ
12.5	−0.113″	11.9	−0.192″	12.5	−0.309″	11.2	−0.369″
27.6	−0.256	25.2	−0.406	26.0	−0.640	25.8	−0.929
40.8	−0.336	40.5	−0.574	40.7	−0.910	40.4	−1.340
62.3	−0.360	62.3	−0.638	62.5	−1.056	62.3	−1.648
81.1	−0.324	81.1	−0.594	81.1	−0.993	81.1	−1.600
123.8	−0.238	123.8	−0 444	123.8	−0.761	123.8	−1.248
184	−0.170	185	−0.285	185	−0.501	184	−0.834
281	−0.101	281	−0.181	279	−0.294	278	−0.490
385	−0.058	389	−0.113	386	−0.179	376	−0.265
510	−0.016	510	−0.055	510	−0.091	510	−0.150
686	+0.074	679	−0.004	683	−0.031	683	−0.049

Annealed cobalt bar.

$C=6.17$ amp.		$C=13.78$ amp.		$C=25.70$ amp.	
H	θ	H	θ	H	θ
35.9	−0.011	35.8	−0.013	36.3	−0.022
81.1	−0.022	81.1	−0.031	81.1	−0.040
186	−0.040	180	−0.055	179	−0.073
269	−0.036	269	−0.053	269	−0.078
400	−0.033	397	−0.054	398	−0.073
492	−0.028	482	−0.045	493	−0.069
691	−0.023	675	−0.038	691	−0.067

Twist by varying the circular field. Fig. 13 represents the result for soft iron ; as the circular field is increased, the twist is increased first slowly and then rapidly. As the longitudinal field is increased, the amount of twist reaches a maximum and then gradually diminishes ; and if the field is strong enough, the twist occurs at first in the opposite direction and then in the ordinary. Comparing the above results with those obtained by varying the longitudinal field, we notice one marked difference that for the same circular and longitudinal fields, the torsion is largely dependent on the order in which they are applied. The twist obtained by first applying the circular field and then the longitudinal is several times greater than the twist obtained, when the order of applying them is reversed.

In nickel, the twist is opposite to that of iron ; under a given longitudinal field, it increases nearly in a constant rate as the longitudinal current is increased, as seen from Fig. 14. For a given longitudinal current, the twist reaches a maximum and then gradually diminishes as the longitudinal field is increased. Here again, we also observe a dependence of the twist on the order of applying longitudinal and circular fields. The twist obtained by the appli-

cation of the circular field followed by that of the longitudinal one is far greater than the twist obtained when the order of application is reversed.

The general feature of the twist for cobalt is similar to that in nickel. In cast cobalt (Fig. 15), the twist is increased first slowly and then rapidly, as the circular field is increased. With the increase of the longitudinal field, the twist reaches a maximum and then gradually diminishes. If the longitudinal field be strong enough, the twist occurs at first in the opposite direction and then in the ordinary. In annealed cobalt (Fig. 16), the twist is very small and the rate of increase is nearly constant. Here also the twist obtained by first applying the circular field and then the longitudinal is several times greater than the twist when the order of application is reversed.

Some observed angles of twist in iron, nickel, and cobalt bars are given in the following tables. Here the current C is given in amperes per square centimeter.

Iron bar.

H=8.2		H=31.7		H=64.1		H=163.4	
C	θ	C	θ	C	θ	C	θ
6.4	0.000″	6.4	0.005″	6.4	0.003″	4.1	−0.002″
9.2	0.005	9.1	0.018	9.2	0.035	6.4	−0.003
13.3	0.015	13.3	0.051	13.4	0.093	9.2	−0.000
17.9	0.038	17.6	0.124	17.9	0.164	13.4	+0.037
24.8	0.109	24.8	0.360	24.7	0.472	17.7	+0.082
28.2	0.145	28.2	0.490	28.3	0.640	28.2	+0.290
37.6	0.203	33.3	0.643	33.3	0.935	33.1	+0.422

Nickel bar.

$H=9.9$		$H=31.7$		$H=72.6$		$H=239.8$	
C	θ	C	θ	C	θ	C	θ
1.0	−0.018″	1.1	−0.042″	1.1	−0.069″	1.1	−0.046″
2.3	−0.040	2.3	−0.109	2.3	−0 155	2.3	−0.112
5.1	−0.106	5.2	−0.285	5.2	−0.371	5.2	−0.256
7.5	−0.163	7.4	−0.395	7.5	−0.552	7.4	−0.373
10.9	−0.259	10.8	−0.621	10.9	−0.837	10.8	−0.555
14.4	−0.413	14.4	−0.891	14.5	−1.157	14.4	−0.749
20.1	−0.652	20.0	−1.372	20.2	−1.732	20.0	−1.078

Cast cobalt bar.

$H=7.4$		$H=65.7$		$H=220.6$		$H=608.0$	
C	θ	C	θ	C	θ	C	θ
1.8	−0.003″	1.9	−0.015″	1.9	−0.002″	0.7	+0.004″
3.7	−0.005	3.7	−0.073	3.7	−0.013	2.5	+0.018
5.9	−0.018	5.9	−0.137	5.9	−0 042	6.4	+0.024
8.5	−0.040	8.5	−0.305	8.5	−0.104	9.3	+0.025
12.4	−0.123	12.4	−0.567	12.5	−0 190	12.5	+0.027
16.5	−0.203	16.5	−0.906	16.6	−0.294	17.6	+0.037
23.0	−0.362	23.1	−1.433	23.0	−0.484	29.8	+0.000
31.8	−0.527	31.6	−2.078	31.5	−0.709	33.3	−0.027

Annealed cobalt bar.

$H=53.8$		$H=157.9$		$H=403.7$	
C	θ	C	θ	C	θ
5.5	−0.001	5.6	−0.002	5.5	−0.004
7.8	−0.002	8.2	−0.005	8.5	−0.009
11.3	−0.004	11.3	−0.009	13.5	−0.015
20.8	−0.009	17.6	−0.015	20.8	−0.026
28.1	−0.014	28.2	−0.027	28.2	−0.034
39.0	−0.019	45.3	−0.053	45.3	−0.061

The effect of torque. To study the effect of torque, it is convenient to keep the longitudinal field constant and to vary the circular field; for though the application of the longitudinal field is always accompanied by the twist due to the change of rigidity, the passage of a longitudinal current does not cause any appreciable twist; hence by varying the circular field, it is not necessary to apply the correction due to the change of rigidity. The torque was given by means of the suspended weights as in the experiment on the change of rigidity by magnetization. Keeping the longitudinal field constant, we found that in all cases the effect of torque diminishes the twist by an amount which is nearly proportional to the torque. Figs. 17, 18, 19, 20 show the general feature of the decrease of twist due to torque. In soft iron and annealed cobalt, the effect is very small, but in nickel and cast cobalt, it is considerable.

In a paper on mutual relations between torsion and magnetism, Professor Nagaoka and one of our members have obtained from Kirchhoff's theory the result that for given longitudinal current and field, the amount of twist is inversely proportional to the square of the radius of the ferromagnetic wire. It is interesting to notice that

the comparison of the above results in iron and nickel bars 1*cm* thick, obtained by varying the longitudinal field, with the corresponding results in wires of these metals about 1*mm* thick, shows the correctness of the law of the inverse square of the radius.

In conclusion, we wish to express our best thanks to Professor H. Nagaoka for useful suggestions in the course of the present experiment.

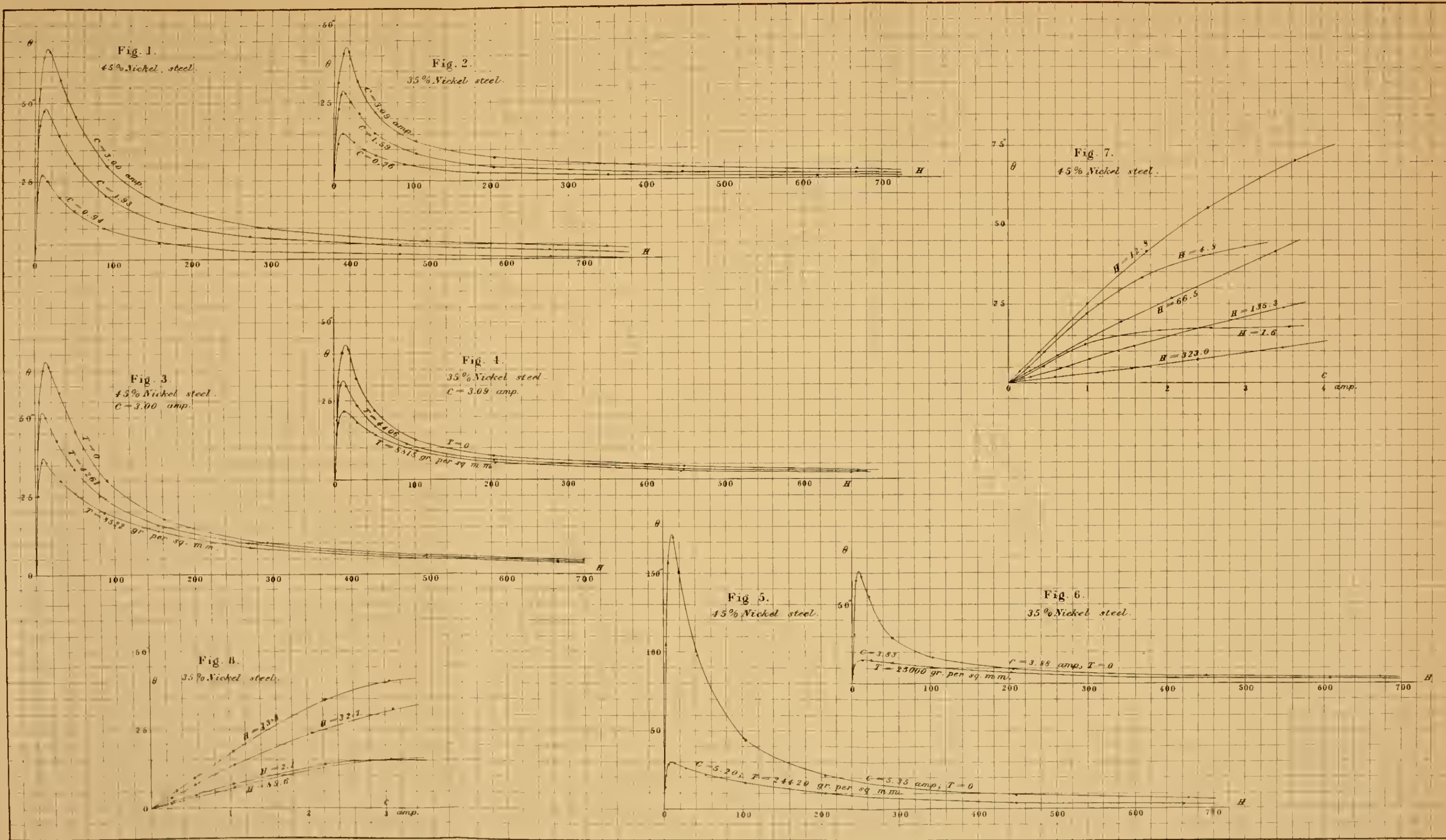


Fig. 1.
45% Nickel. steel.
C = 3.00 amp.
C = 1.93
C = 0.94
Fig. 2.
35% Nickel steel.
C = 3.09 amp.
C = 1.59
C = 0.76
Fig. 3.
45% Nickel steel.
C = 3.00 amp.
T = 0
T = 4261
T = 4522 gr. per sq. m.m.
Fig. 4.
35% Nickel steel.
C = 3.09 amp.
T = 0
T = 4406
T = 5513 gr. per sq. m.m.
Fig. 5.
45% Nickel steel.
C = 5.35 amp, T = 0
C = 5.20, T = 24420 gr. per sq. m.m.
Fig. 6.
35% Nickel steel.
C = 3.88 amp, T = 0
C = 3.83
T = 23000 gr. per sq. m.m.
Fig. 7.
45% Nickel steel.
H = 12.9
H = 4.5
H = 66.5
H = 135.3
H = 1.6
H = 323.0
Fig. 8.
35% Nickel steel.
H = 13.4
H = 32.1
H = 2.1
H = 153.6

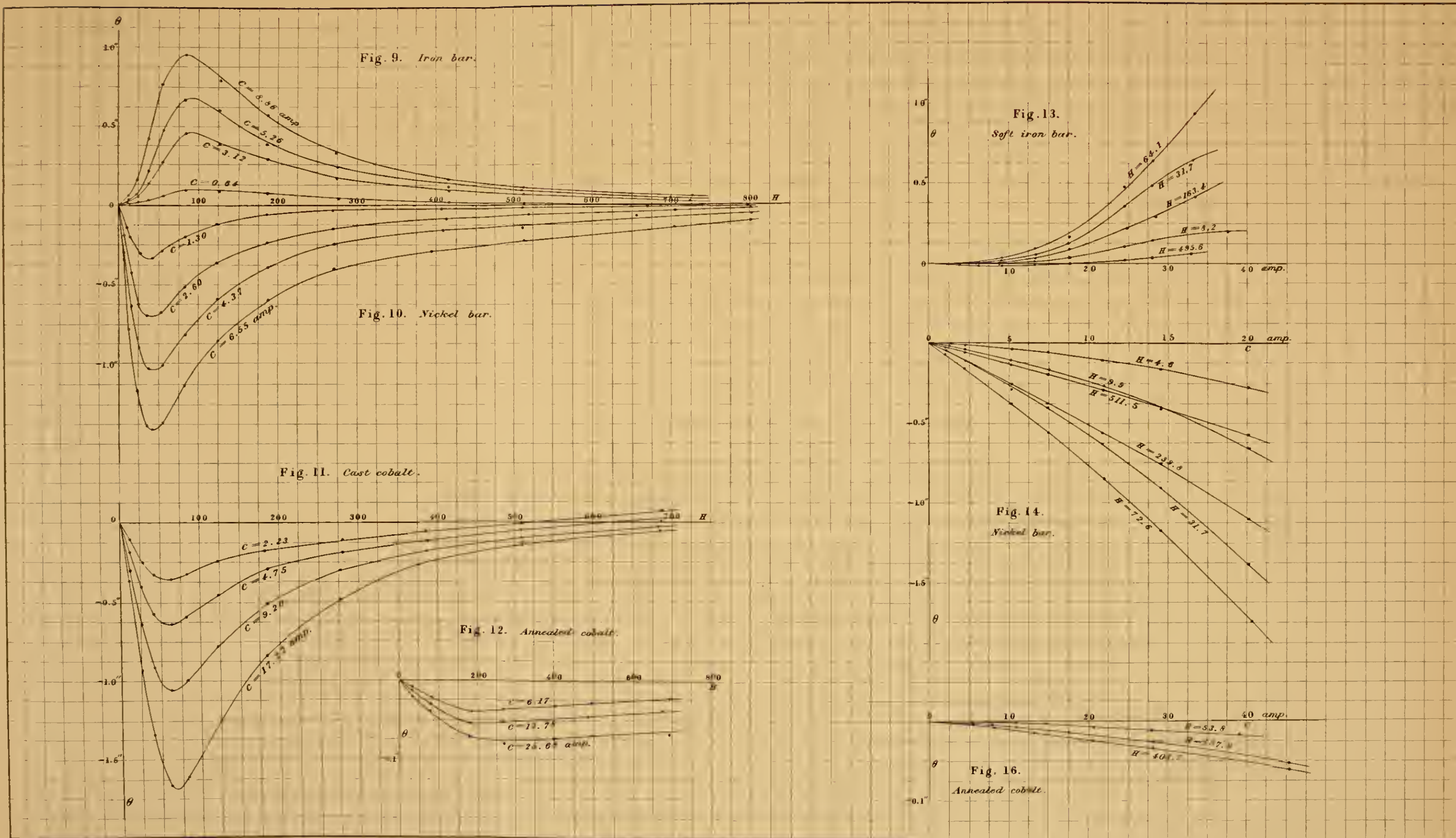


Fig. 9. *Iron bar.*

Fig. 10. *Nickel bar.*

Fig. 11. *Cast cobalt.*

Fig. 12. *Annealed cobalt.*

Fig. 13. *Soft iron bar.*

Fig. 14. *Nickel bar.*

Fig. 16. *Annealed cobalt.*

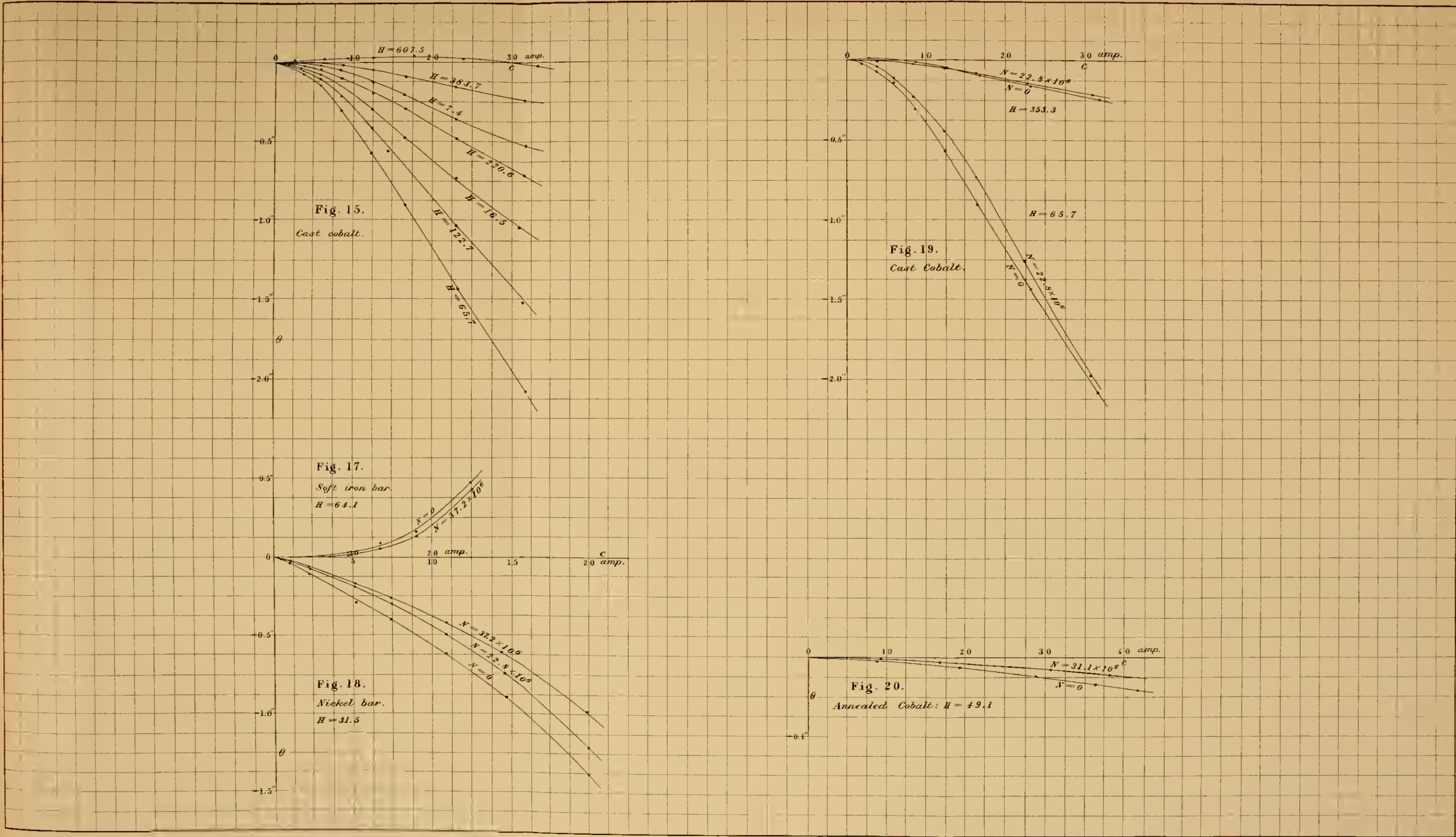


Fig. 15.
Cast cobalt.
H = 607.5
H = 383.7
H = 7.4
H = 220.6
H = 16.5
H = 122.7
H = 65.7
Fig. 19.
Cast Cobalt.
N = 22.8 × 10^6
N = 0
H = 353.3
H = 65.7
Fig. 17.
Soft iron bar.
H = 64.1
N = 0
N = 37.2 × 10^6
Fig. 18.
Nickel bar.
H = 31.5
N = 37.2 × 10^6
N = 22.8 × 10^6
N = 0
Fig. 20.
Annealed Cobalt: H = 49.1
N = 31.1 × 10^6
N = 0
amp.
θ

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Note on the Potential and the Lines of Force of a Circular Current.

By

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§ 1. The potential of a circular electric current or of a vortex ring of small section, has been investigated by Lord Kelvin,[1] Maxwell[2] Hicks,[3] and Minchin.[4] They all express the solid angle subtended by the circle by means of elliptic integrals or in terms of zonal spherical harmonics. The lines of force of a circular current are usually obtained from the expression for the mutual potential energy (denoted by M) of two coaxial circular coils. By using F. Neumann's formula, M may be expressed by means of elliptic integrals, or developed in terms of zonal harmonics, which is sometimes advantageous for calculating the action between thick coils. Maxwell has also given a table of the coefficients of mutual induction, when the coils are near each other. In these calculations we are always in need of Legendre's tables. It is very curious that so

1) Lord Kelvin, Trans. R. S. E., 1869.
2) Maxwell, Treatise on Electricity and Magnetism II. Chap. 14.
3) Hicks, Phil. Trans. for 1881, p. 628.
4) Minchin, Phil. Mag. vol. 35, 1893.

little use has been made of Jacobi's q-series. Mathy[1] uses Weierstrass's $\wp$-function in evaluating M, but he seems to be inclined to the use of a hypergeometric series, rather than to the reduction of these integrals to a rapidly converging q-series, to which the expression can be easily transformed.

The problem can, however, be attacked from another point of view. In the following, I proceed by finding the Newtonian potential of an uniform circular disc, and derive the expression for the potential and the lines of force for a circular current by simple differentiation. Finally M is expressed by means of a simple q-series, of which a single term will generally suffice to secure a practically accurate value; the force between two coaxial coils can also be expressed in a similar manner.

§ 2. The whole investigation rests on the following lemma.

The potential U of an homogeneous body of rotation (about z-axis) satisfies Laplace's equation outside the body, which in this case is given by

$$\frac{\partial^2 U}{\partial z^2} + \frac{\partial^2 U}{\partial x^2} + \frac{1}{x}\,\frac{\partial U}{\partial x} = 0.$$

x being the radial coordinate. Thus

$$\frac{\partial^2 U}{\partial z^2} = -\frac{1}{x}\,\frac{\partial}{\partial x}\left(x\,\frac{\partial U}{\partial x}\right)$$

and

$$\frac{\partial^2 U}{\partial x\,\partial z} = \frac{1}{x}\,\frac{\partial}{\partial z}\left(x\,\frac{\partial U}{\partial x}\right)$$

If the potential φ of a certain distribution symmetrical about z-axis be derivable from U by differentiation with respect to z, so that

$$\varphi = \frac{\partial U}{\partial z} \qquad \text{(I.)}$$

1) Mathy, Journal de Physique, tom. 10, p. 33, 1901.

and if $$\psi = x\frac{\partial U}{\partial x}\ , \qquad \text{(II.)}$$

then since

$$\frac{\partial \varphi}{\partial x}\ \frac{\partial \psi}{\partial x} + \frac{\partial \varphi}{\partial z}\ \frac{\partial \psi}{\partial z} = 0. \quad ,$$

$$\psi = \text{const.}$$

must represent lines of force.

The potential of a circular current is equivalent to that of a magnetic shell, which is derivable from the Newtonian potential of a uniform disc, by differentiation with respect to the normal.

§ 3. *Potential of a uniform circular disc.*—Let the surface density $=1$; then taking x, y axes in the plane of the disc, and z axis perpendicular to it through the centre, the potential at point x, o, z is evidently given by

$$U = \int_0^a \int_0^{2\pi} \frac{\rho\, d\rho d\,\theta}{\sqrt{x^2 - 2\,x\,\rho\,\cos\theta + \rho^2 + z^2}} \qquad (1)$$

ρ and θ being polar coordinates, and a the radius of the disc.

Writing $R^2 = x^2 - 2x\,\rho\,\cos\theta + \rho^2$, and making use of Lipschitz's integral concerning the Bessel's function, we obtain

$$\frac{1}{\sqrt{x^2 - 2x\,\rho\,\cos\theta + \rho^2 + z^2}} = \frac{1}{\sqrt{R^2 + z^2}} = \int_0^\infty e^{-\lambda z} J_0(R\,\lambda)\, d\,\lambda. \qquad (2)$$

The addition theorem of Bessel's functions gives

$$J_0(\lambda\, R) = J_0(\lambda\, x)\, J_0(\lambda\rho) + 2\sum_1^\infty J_n(\lambda\, x)\, J_n(\lambda\rho)\cos n\,\theta. \qquad (3)$$

Substituting in (2), we get

$$U = \int_0^\infty \int_0^a \int_0^{2\pi} \rho\, e^{-\lambda z}\, \{J_0(\lambda x)\, J_0(\lambda\,\rho) + 2\sum_1^\infty J_n(\lambda\, x)\, J_n(\lambda\rho)\cos n\,\theta\}\, d\lambda\, d\rho\, d\theta.$$

$$= 2\pi \int_0^\infty \int_0^a e^{-\lambda z}\, \rho\, J_0(\lambda x)\, J_0(\lambda\rho)\, d\lambda\, d\rho.$$

But $$\rho\, J_0(\lambda\rho)=\frac{d(\rho\, J_0(\lambda\rho))}{\lambda\, d\rho}$$

Thus the potential of a circular disc is given by

$$U=2\,\pi\, a\int_0^\infty \frac{e^{-\lambda z}}{\lambda}\, J_0(\lambda x)\, J_1(\lambda a)\, d\lambda. \tag{4}$$

This expression was first obtained by H. Weber[1] in a somewhat different manner.

§ 4. *Potential and lines of force of a uniform circular magnetic shell.*—The potential of a circular magnetic shell of unit strength is evidently given by

$$\varphi=-\frac{\partial U}{\partial z}=2\,\pi\, a\int_0^\infty e^{-\lambda z}\, J_0(\lambda\, x)\, J_1(\lambda\, a)\, d\,\lambda, \tag{A}$$

and for the function giving lines of force

$$\psi=-x\frac{\partial U}{\partial x}=2\pi a x\int_0^\infty e^{-\lambda z}\, J_1(\lambda\, x)\, J_1(\lambda\, a)\, d\,\lambda. \tag{B}$$

The two expressions (A) and (B) can be greatly simplified by using the addition theorem for $J_0(R\,\lambda)$ and $J_1(R\,\lambda)$.

Differentiating (3) with respect to ρ and integrating between the limits 0 and π of θ,
we obtain

$$J_0(\lambda x)\, J_1(\lambda a)=\frac{1}{\pi}\int_0^\pi \frac{J_1(\lambda R)}{R}\,(a-x\cos\theta)\, d\,\theta.$$

Similarly

$$J_1(\lambda x)\, J_1(\lambda a)=\frac{2}{\pi}\int_0 J_0(\lambda R)\cos\theta\, d\theta.$$

1) H. Weber, Crelle's Journal, Bd. 75, p. 88.

Remembering that

$$\int_0^\infty e^{-\lambda z}\, J_1(\lambda R)\, d\lambda = \frac{1}{R} - \frac{z}{R\sqrt{R^2+z^2}} \quad ,$$

$$\int_0^\infty e^{-\lambda z}\, J_0(\lambda R)\, d\lambda = \frac{1}{\sqrt{R^2+z^2}} \quad ,$$

we find by simple substitution

$$\varphi = 2a\int_0^\pi \frac{a - x\cos\theta}{R^2}\, d\,\theta - 2a\, z\int_0^\pi \frac{(a - x\cos\theta)}{R^2\sqrt{R^2+z^2}}\, d\,\theta \tag{5}$$

and

$$\psi = 4ax\int_0^\pi \frac{\cos\theta\, d\theta}{\sqrt{R^2+z^2}} \tag{6}$$

But we easily find that

$$\int_0^\pi \frac{(a - x\cos\theta)\, d\theta}{R^2} = \frac{\pi}{a} \quad ,$$

whence by (5)

$$\varphi = 2\pi - 2az\int_0^\pi \frac{(a - x\cos\theta)\, d\theta}{(a^2+x^2-2ax\cos\theta)\sqrt{a^2+x^2+z^2-2ax\cos\theta}} \tag{A'}$$

The above expression gives the solid angle subtended by the disc at point (x, o, z).

Evidently the coefficient of mutual induction M of two parallel coaxial coils is connected with ψ by the relation

$$\pi\,\psi = M. \tag{7}$$

Consequently, (6) gives

$$M = 4\,\pi\, ax\int_0^\pi \frac{\cos\theta\, d\theta}{\sqrt{a^2+x^2+z^2-2\,ax\cos\theta}} \tag{B'}$$

This expression coincides with that obtained in the usual manner from F. Neumann's formula.

§ 5. *Evaluation of φ or solid angle subtended by a circle.*—Denoting the integral entering in (A') by Ω, we have

$$\Omega=2\,az\int_0^\pi\frac{(a-x\cos\theta)\,d\theta}{(a^2+x^2-2ax\cos\theta)\sqrt{a^2+x^2+z^2-2ax\cos\theta}}\tag{8}$$

Putting $\cos\theta=As+B$, where

$$A=\left(\frac{2}{ax}\right)^{\frac{1}{3}},\tag{9}$$

$$B=\frac{a^2+x^2+z^2}{ax},$$

we easily find

$$\sin\theta\sqrt{a^2+x^2+z^2-2\,ax\cos\theta}=\sqrt{4\,(s-e_1)\,(s-e_2)\,(s-e_3)}$$
$$=\sqrt{4\,s^3-g_2\,s-g_3}=\sqrt{S}$$

where

$$e_1=\frac{2B}{A}\quad,\quad e_2=\frac{1-B}{A}\quad,\quad e_3=-\frac{(1+B)}{A}.\tag{10}$$

$$\frac{1}{4}\,g_2=\frac{3B^2-1}{A^2}\quad,\quad\frac{1}{4}\,g_3=\frac{2\,B\,(B^2-1)}{A^3}\quad.$$

$$G=\left\{\frac{(a^2+x^2+z^2)^2-4\,a^2\,r^2}{4\,ar}\right\}^2,$$

whence

$$k^2=\frac{2}{1+3\,B}=\frac{4\,ax}{(a+x)^2+z^2},$$
$$k'^2=\frac{3\,B-1}{3\,B+1}=\frac{(a-x)^2+z^2}{(a+x)^2+z^2}.\tag{11}$$

Thus, putting

$$u=\int_s^\infty \frac{ds}{\sqrt{S}} \qquad \text{or} \qquad s=\wp(u)$$

$$\Omega=A\,z\int_{\omega 2}^{\omega 3} du+z\,(a^2-x^2)\int_{\omega 2}^{\omega 3}\frac{du}{a^2+x^2-2a\,x\,(A\,\wp(u)+B)}. \tag{12}$$

Let

$$\wp(a)=\frac{2\,(a^2+x^2)-z^2}{6\,ax\,A}\quad,$$

then

$$\wp'(a)=-\sqrt{4\,\wp^3(a)-g_2\,\wp(a)-g_3}=-i\,\frac{z\,(a^2-x^2)}{2\,ax}$$

and

$$\Omega=\omega_1\,A\,z+i\int_{\omega 2}^{3}\frac{\wp'(a)}{\wp(a)-\wp(u)}\,du. \tag{13}$$

Evaluating the last integral, we arrive at the result

$$\Omega=\frac{2\omega_1}{e_2-e_3}\,z+2\,i\left\{\eta_1 a-\omega_1\frac{\sigma'}{\sigma}(a)\right\}. \tag{14}$$

Thus the potential of a circular current or of a vortex ring is given by

$$\varphi=2\,\pi-2\left[\frac{\omega_1\,z}{e_2-e_3}+i\left\{\eta_1\,a-\omega_1\frac{\sigma'}{\sigma}(a)\right\}\right] \tag{A''}$$

$$=2\,\pi-\frac{\pi\,\vartheta_2^2(o)}{\sqrt{e_2-e_3}}\,z-i\,\frac{\vartheta_1'\,(v_a i)}{\vartheta_1\,(v_a i)}\quad \text{where}\quad v_a=\frac{a}{2\omega_1}i$$

The form of integral (A′) is somewhat different from that given by Hicks and Minchin, but it leads to the same result. The process of reduction from the expressions given by the above mentioned authors is more laborious.

In practical calculation, the part requiring the most painstaking is the evaluation of a, for which the expressions given in Prof. Schwarz's "Formeln und Lehrsätze zum Gebrauche der elliptischen Functionen" p. 71. will be found very useful. For convenience in calculation, the following values of $\wp(a)-e_\lambda$ have been tabulated

$$\wp(a)-e_1=-\frac{1}{A}\frac{z^2}{2ax}=-\frac{z^2}{4ax}(e_2-e_3)$$

$$\wp(a)-e_2=\frac{1}{A}\frac{(a-x)^2}{2ax}=\frac{(a-x)^2}{4ax}(e_2-e_3) \qquad (15)$$

$$\wp(a)-e_3=\frac{1}{A}\frac{(a+x)^2}{2ax}=\frac{(a+x)^2}{4ax}(e_2-e_3)$$

Thus $e_2<\wp(a)<e_1$

$$e_2-e_3=\frac{2}{A}=2\left(\frac{ax}{2}\right)^{\frac{1}{3}}$$

$$e_1-e_3=\frac{1}{A}\frac{(a+x)^2+z^2}{2ax}=\frac{(a+x)^2+z^2}{4ax}(e_2-e_3)$$

$$e_1-e_2=\frac{1}{A}\frac{(a-x)^2+z^2}{2ax}=\frac{(a+x)^2+z^2}{4ax}(e_2-e_3)$$

Putting

$$\frac{\sqrt[4]{e_1-e_3}\sqrt{\wp(a)-e_2}-\sqrt[4]{e_1-e_2}\sqrt{\wp(a)-e_3}}{\sqrt[4]{e_1-e_3}\sqrt{\wp(a)-e_2}+\sqrt[4]{e_1-e_2}\sqrt{\wp(a)-e_3}}=lt \quad \text{where} \quad l=\frac{1-\sqrt{k'}}{1+\sqrt{k'}}$$

and
$$\mathfrak{L}_0=1+\left(\frac{1}{2}\right)^2l^4+\left(\frac{1.3}{2.4}\right)^2l^8+\left(\frac{1.3.5}{2.4.6}\right)^2l^{12}+\cdots\cdots$$

$$\mathfrak{L}_{0,1}=\left(\frac{1}{2}\right)^2l^4+\left(\frac{1.3}{2.4}\right)^2l^8+\left(\frac{1.3.5}{2.4.6}\right)^2l^{12}+\cdots\cdots$$

$$\mathfrak{L}_{0,2}=\left(\frac{1.3}{2.4}\right)^2l^8+\left(\frac{1.3.5}{2.4.6}\right)^2l^{12}+\cdots\cdots$$

....

we find after a simple calculation, that

$$\frac{a}{2\omega_1}\pi i = v_a \pi$$

$$= -\frac{1}{2} \log (t + \sqrt{t^2-1}) - \frac{1}{2}\sqrt{t^2-1} \left(\frac{\mathfrak{L}_{0,1}}{\mathfrak{L}_0} t + \frac{2}{3} \frac{\mathfrak{L}_{0,2}}{\mathfrak{L}_0} t^3 + \ldots\ldots \right)$$

Since $\mathfrak{L}_0$, $\mathfrak{L}_{0,2}, \ldots\ldots$ are generally small quantities, the second term will be very small as compared with the first. Further we notice that

$$i\left\{\eta\, a - \omega_1 \frac{\sigma'}{\sigma}(a)\right\} = \frac{\pi}{2}\left\{ \frac{e^{v_a \pi} + e^{-v_a \pi}}{e^{v_a \pi} - e^{-v_a \pi}} \right.$$

$$\left. + \sum{}' \frac{2q^{2n}\, e^{-2v_a \pi}}{1-q^{2n}\, e^{-2v_a \pi}} - \sum{}' \frac{2q^{2n}\, e^{2v_a \pi}}{1-q^{2n}\, e^{2v_a \pi}} \right\}$$

Thus the calculation of the solid angle subtended by a circle can be easily undertaken without the use of special tables.

§ 6. *Evaluation of M or the coefficient of mutual induction of two coaxial coils.*—As has already been noticed, M=const. gives magnetic lines of force about a circular current, or stream lines about a circular vortex ring of infinitely small section. Reverting to (B′), (9), (10), and (11), we find that

$$M = 4\pi a x \int_0^{\pi} \frac{\cos\theta\, d\theta}{\sqrt{a^2+x^2+z^2-2\,ax\cos\theta}}$$

$$= 4\pi\, a x\, A \int_{\omega_3}^{\omega_2} (A\, \wp(u) + B)\, du \qquad (16)$$

Thus the expression for M can be written in either of the following forms :—

$$M = 4\pi\, a x \frac{A^2}{\omega_1}\left(\frac{e_1\, \omega_1^2}{2} - \eta_1\, \omega_1 \right) \qquad (B_1'')$$

or

$$M = 4\pi\, a x \frac{A^2}{\omega_3}\left(\frac{e_1\, \omega_1\, \omega_3}{2} - \eta_1\, \omega_3 \right) \qquad (B_2'')$$

§ 7. *M expressed in terms of ϑ-functions.*—Since

$$e_1\,\omega_1^2 = -\eta_1\,\omega_1 - \frac{1}{4}\;\frac{\vartheta_2''(o)}{\vartheta_2(o)}\quad,$$

$$\eta_1\,\omega_1 = -\frac{1}{12}\frac{\vartheta_1'''(o)}{\vartheta_1'(o)}\quad,$$

and

$$\frac{A^2}{\omega_1} = \frac{4}{\pi\sqrt{ax}\,\vartheta_2^2(o)}$$

we find from (B_1'')

$$M = \frac{2\sqrt{ax}}{\vartheta_2^2\,(o)}\;\left\{\frac{\vartheta_1'''(o)}{\vartheta_1'(o)} - \frac{\vartheta_2''(o)}{\vartheta_2(o)}\right\} \tag{17}$$

Using the relations

$$\frac{\vartheta_1'''(o)}{\vartheta_1'(o)} = -4\,\pi^2\,\frac{\partial\,log\,\vartheta_1'(o)}{\partial\,log\,q}\quad,$$

$$\frac{\vartheta_2''(o)}{\vartheta_2(o)} = -4\,\pi^2\,\frac{\partial\,log\,\vartheta_2(o)}{\partial\,log\,q}$$

$$\vartheta_1'(o) = \pi\vartheta_0(o)\;\vartheta_2(o)\;\vartheta_3(o)\quad,$$

we can write

$$M = -\frac{2\sqrt{ax}}{\vartheta_2^2(o)}\left(\frac{\vartheta_0''(o)}{\vartheta_0\,(o)} + \frac{\vartheta_3''(o)}{\vartheta_3(o)}\right) \tag{18}$$

Utilizing the relation

$$\eta_1\,\omega_3 = \eta_3\,\omega_1 - \frac{1}{2}\pi\,i$$

we may put (B_2'') in the form

$$M = 4\pi\,ax\frac{A^2}{\omega_3}\left\{\frac{\omega_1}{\omega_3}\,(e_1\,\omega_3^2 - \eta_3\,\omega_3) + \frac{1}{2}\,\pi\,i\right\}$$

Writing $\tau_1 = -\frac{\omega_1}{\omega_3}$, we easily find that

$$M=4\pi ax\frac{A^2}{\omega_3}\left\{\frac{1}{8\tau}\left(\frac{\vartheta_2''(o)}{\vartheta_2(o)}+\frac{\vartheta_3''(o)}{\vartheta_3(o)}\right)+\frac{1}{2}\pi i\right\}$$

$$=\frac{8\sqrt{ax}}{\pi\vartheta_0^2(o\mid\tau_1)}\left\{\pi^2-\frac{\log\left(\frac{1}{q_1}\right)}{4}\left(\frac{\vartheta_2''(o\mid\tau_1)}{\vartheta_2(o\mid\tau_1)}+\frac{\vartheta_3''(o\mid\tau_1)}{\vartheta_3(o\mid\tau_1)}\right)\right\} \tag{19}$$

The expressions (17), (18), and (19) are of great practical importance, as will be shown in another section.

§ 8. *Expression for* $\frac{\partial M}{\partial z}$. In addition to M, we shall have to find $\frac{\partial M}{\partial z}$, which represents the force acting between two coaxial coils Since

$$\frac{\partial M}{\partial z}=4\pi axz\int_0^\pi\frac{\cos\theta\, d\theta}{(a^2+x^2+z^2-2ax\cos\theta)^{\frac{3}{2}}}, \tag{20}$$

we easily find that

$$\frac{1}{4\pi ax}\frac{\partial M}{\partial z}=-\frac{A^4z}{4}\int_{\omega_3}^{\omega_2}\frac{A\wp(u)+B}{A\wp(u)-2B}du$$

$$=-\frac{A^4z}{4}\left\{\omega_1-\frac{3e_1}{2(e_1-e_2)(e_1-e_3)}(\eta_1+e_1\omega_1)\right\} \tag{21}$$

Expressing e_1, e_1-e_2, e_1-e_3, by means of ϑ-functions,

$$\frac{\partial M}{\partial z}=-\frac{\pi z}{\sqrt{ax}}\left\{\vartheta_2^2(o)+\frac{1}{2\pi^2}\left(\frac{1}{\vartheta_0^4(o)}+\frac{1}{\vartheta_3^4(o)}\right)\vartheta_2''(o)\,\vartheta_2(o)\right\} \tag{22}$$

§ 9. *M expressed in q-series.*—For reducing the ϑ-functions in (17) and (18), we can conveniently make use of the expansions given by Jacobi (Fundamenta Nova p. 104–105, Gesammelte Werke Bd. 1. p. 161). As the result of expansion, we easily find that

$$\frac{M}{4\pi\sqrt{ax}}=4\pi q^{\frac{3}{2}}(1+*+3q^4-4q^6+9q^8-12q^{10}\ldots\ldots\ldots) \tag{23}$$

Putting

$$3q^4-4q^6+9q^8-12q^{10}+\cdots\cdots\cdots=\varepsilon,$$

we can conveniently write

$$\frac{M}{4\pi\sqrt{ax}} = 4\pi q^{\frac{3}{2}}(1+\varepsilon) \tag{24}$$

Since ε is a very small quantity, we can, with tolerable accuracy, put

$$M \doteq 16\pi^2\sqrt{ax}\, q^{\frac{3}{2}} \tag{25}$$

Expressing (19) by means of q_1,

$$\frac{M}{4\pi\sqrt{ax}} = \frac{1}{2(1-2q_1+2q_1^4-2q_1^9)^2}\left[log\left(\frac{1}{q_1}\right)\left\{1+8q_1(1-q_1+4q_1^2-5q_1^3\right.\right.$$

$$\left.\left.+6q_1^4-4q_1^5+8q_1^6-13q_1^7+\ldots\ldots)\right\}-4\right] \tag{26}$$

The above expression is useful when the coils are very near each other. In such cases, q_1 is a very small quantity, so that by putting

$$32q_1^3-40q_1^4+48q_1^5-32q_1^6=\varepsilon_1$$

$$\frac{M}{4\pi\sqrt{ax}} = \frac{1}{2(1-2q_1+2q_1^4)^2}\left[log\left(\frac{1}{q_1}\right)\left\{1+8q_1(1-q_1)+\varepsilon_1\right\}-4\right] \tag{27}$$

For $\gamma>70^\circ$, where $sin\,\gamma=k$, q_1^3 is negligibly small, and

$$\frac{M}{4\pi\sqrt{ax}} \doteq \frac{1}{2(1-2q_1)^2}\left[log\left(\frac{1}{q_1}\right)\left\{1+8q_1+\varepsilon_1'\right\}-4\right] \tag{28}$$

$$\text{where } \varepsilon_1' = -8q_1^2+\varepsilon_1$$

Finally (22) gives

$$\frac{\partial M}{\partial z} = \frac{192\pi^2 z}{\sqrt{ax}}\, q^{\frac{5}{2}}(1+20q^2+225q^4+1840q^6+12120q^8+\cdots\cdots) \tag{29}$$

It will not be altogether out of place to digress on the practical utility of the several formulae above obtained.

In the first place, there is no need of finding γ from k or k',

which is given at once from the dimensions and configuration of the coils. Instead of finding γ, we shall have to calculate

$$q=\frac{1}{2}l+2\left(\frac{1}{2}l\right)^5+15\left(\frac{1}{2}l\right)^9+\cdots\cdots$$

where $$l=\frac{1-\sqrt{k'}}{1+\sqrt{k'}},$$

of which the first term is generally sufficient,[1] as the following short table for $q-\frac{l}{2}$ will show. For practical purposes, a single calculation according to formula (25) or (27) gives at once the value of M. In order to shew the rapid convergence of the q-series, it will be sufficient to indicate the smallness of the corrections ε and ε_1, ε_1' entering in the above two formulae. For this purpose, the following short tables of corrections have been calculated.

Table of $\varepsilon=3q^4-4q^6+9q^8-12q^{10}$ and $q-\frac{l}{2}$

q.	Approximate value of γ=arc sin k.	ε	$q-\frac{l}{2}$
0.01	22°.6	0.000 0000	0.000 00000
0.02	31°.6	0.000 0005	0.000 00001
0.03	38°.1	0.000 0024	0.000 00005
0.04	43°.5	0.000 0077	0.000 00020
0.05	48°.0	0.000 0187	0.000 00063
0.06	51°.9	0.000 0387	0.000 00156
0.07	55°.3	0.000 0726	0.000 00336
0.08	58°.4	0.000 1218	0.000 00655
0.09	61°.1	0.000 1947	0.000 01181
0.10	63°.6	0.000 2961	0.000 02000
0.11	65°.9	0.000 4323	0.000 03220
0.12	67°.9	0.000 6105	0.000 04974
0.13	69°.8	0.000 8382	0.000 07421
0.14	71°.5	0.001 1234	0.000 10746

1) For the table of q, see Jacobi, Crelle's Journal Bd. 26, p. 93: Gesammelte Werke, Bd. 1, p. 363.

γ=arc sin k.	ε
10°	0.000 00000
20°	0.000 00000
30°	0.000 00031
40°	0.000 00367
45°	0.000 01044
50°	0.000 02738
55°	0.000 06773
60°	0.000 16098
65°	0.000 37397
70°	0.000 86566

Table of $\varepsilon_1=32\,q_1^3-40\,q_1^4+48\,q_1^5-32\,q_1^6$

$$\varepsilon_1'=-8q_1^2+\varepsilon_1.$$

q_1	Approximate value of γ=arc sin k.	ε_1	ε_1'
0.010	67°.4	0.000 0316	−0.000 7684
0.009	68°.5	0.000 0231	−0.000 6249
0.008	69°.7	0.000 0162	−0.000 4958
0.007	71°.0	0.000 0109	−0.000 3811
0.006	72°.4	0.000 0069	−0.000 2811
0.005	73°9	0.000 0040	−0.000 1960
0.004	75°.6	0.000 0020	−0.000 1260
0.003	77°.5	0.000 0010	−0.000 0710
0.002	79°.8	0.000 0003	−0.000 0317
0.001	82°.8	0.000 0000	−0.000 0080

The table shows that the error in M calculated by the formula

$$\frac{M}{4\pi\sqrt{ax}} \doteqdot 4\pi\, q^{\frac{3}{2}}$$

is only 0.001 per cent for $\gamma=45^0$, and 0.09 per cent for $\gamma=70^0$. When the coils are near each other, the approximation can be carried still further by using (27). In all these calculations, Legendre's table of elliptic integrals may be dispensed with; a somewhat tedious operation lies in finding $log\, nat\left(\frac{1}{q_1}\right)$.

It will not be out of place to give a numerical value for a single instance, in order to shew the rapid convergence of (23). For $k=\sin 70^0$,

$$q=0.1309845\left(=\frac{1}{2}l\right)+0.0000771\left(=2\left(\frac{1}{2}l\right)^5\right)+0.0000002\left(=15\left(\frac{1}{2}l\right)^9\right)$$

$$=0.1310618$$

$$log\,\frac{M}{4\pi\sqrt{ax}}=\bar{1}.7754242\left(=log\,4\pi q^{\frac{3}{2}}\right)+0.0003758\left(=log\,(1+\varepsilon)\right)$$

$$=\bar{1}.7758000.$$

which coincides with the value given by Maxwell. It is to be noticed, that the above is the most unfavorable case in which (24) may be applied.

§ 10. It will be worth while to mention that the expression for the solid angle subtended by a circle, in terms of zonal harmonics, can be deduced from the formulae already obtained.

The potential of a magnetic shell φ is given by (A).

$$\varphi=2\pi a\int_0^\infty e^{-\lambda z}\,J_0(\lambda x)\,J_1(\lambda a)\,d\lambda$$

By expanding $J_1(\lambda a)$ according to ascending powers of λa, and remembering that

$$\int_0^\infty e^{-\lambda z} J_0(\lambda z)\,\lambda^{2m+1} d\lambda = 1.2.3\ldots\ldots(2m+1)(x^2+z^2)^{-m+1} P_{2m+1}\left(\frac{z}{\sqrt{x^2+z^2}}\right),$$

where P_{2m+1} denotes zonal harmonics of $2m+1$th order, we arrive at the ordinary expression for the solid angle in terms of spherical harmonics. M can be similarly expressed by using (B′).

It is needless to remark that such expansions converge very slowly. What I wish to show in the present paper is that we may sometimes arrive at a convenient and practical result by using a q-series, instead of falling into the grooves of spherical harmonics.

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